

Unequal Vaccines? A Mixed Methods Study Exploring Socioeconomic Inequalities in Routine Vaccination Uptake in a Post-COVID-19 Era.

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This thesis is dedicated to

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Abstract

Introduction: The COVID-19 pandemic heightened global attention on vaccination and exacerbated health inequalities, particularly among those experiencing socioeconomic disadvantage. However, existing literature has not adequately explored the pandemic's impact on socioeconomic inequalities in routine vaccination uptake.

Aim: To understand and map the narrative and state of socioeconomic inequalities in vaccination uptake in a post-COVID-19 era.

Methods: This project comprised two components: (1) an umbrella systematic review of global socioeconomic inequalities in routine vaccination uptake, and (2) a mixed methods study in England, focused on childhood vaccinations. The quantitative element used piecewise regressions to analyse the effects of COVID-19 and socioeconomic deprivation on MMR and pre-school booster uptake. The qualitative aspect involved interviews with professionals commissioning, supporting, and monitoring the childhood vaccination programme in the North East of England, focusing on areas of high socioeconomic deprivation. Transcripts were analysed using a framework approach.

Findings: The umbrella review findings were complex. Lower routine vaccination uptake was identified across both advantaged and disadvantaged socioeconomic groups. Mechanisms, such as knowledge and confidence in vaccination and/or providers) were often understood to vary by level of education. The mixed methods study found complementary evidence. A COVID-19-associated decline in childhood vaccination uptake was identified, although rates were declining beforehand. The North East of England, an area of high socioeconomic deprivation, often achieved higher uptake levels than other regions. Despite this, interviewees spoke of pockets of low uptake within the North East and greater challenges faced by vaccination providers in socioeconomically deprived areas. Families with challenging personal lives were reportedly at a greater risk of low uptake.

Conclusion: Vaccination uptake manifests differently from other healthcare interventions. Vaccination services that reflect the needs of the target population are required to improve uptake, regardless of socioeconomic position. Equitable funding

that acknowledges the complexities of provision in underserved communities is warranted.

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Abbreviations

4-in-1 – pre-school booster, Diphtheria, Tetanus, Pertussis and Polio

6-in-1 – Diphtheria, Tetanus, Pertussis, Polio Haemophilus influenzae type B, and Hepatitis B

AMSTAR-2 – A MeaSurement Tool to Assess Systematic Reviews, version 2

ASSIA – Applied Social Sciences Index and Abstracts

BCG –Bacillus Calmette-Guérin, Tuberculosis vaccine

BMJ - British Medical Journal

BSAS – British Social Attitudes Survey

CCA – corrected coverage area

CDC – Centre for Disease Control and Prevention

CHIS – Child Health Information Services

CI – confidence intervals

CINAHL – Cumulative Index to Nursing and Allied Health Literature

COREQ – consolidated criteria for reporting qualitative research

COVER – Cover of Vaccinations Evaluated Rapidly

COVID-19 – Coronavirus Pandemic 2019

CPI – Contractor Population Index

CPRD – Clinical Practice Research Datalink

CRP – Contractor’s Registered Population

CSV – comma-separated values

DARE – Database of Abstracts of Reviews of Effects

DHSC – Department of Health and Social Care

DNA – did not attend

DTaP – Diphtheria, Tetanus and Pertussis vaccine

DTaP/IPV – Diphtheria, Tetanus, Pertussis, and Inactivated Polio vaccine

EPI – Expanded Programme on Immunisation.

Flu – influenza

GDP – gross domestic product

GMS – General Medical Service Contracts

GP – general practitioner

HepB – Hepatitis B

Hib – Haemophilus Influenzae type b

HIC – high-income countries

HPV – Human Papillomavirus

HRA – Health Research Authority

ICB – Integrated Care Board

ICP – Integrated Care Partnerships

ICS – Integrated Care Systems

IMD – Indices of Multiple Deprivation

IoD – English Indices of Deprivation

IPV – inactivated Poliovirus

ISSG - InterTASC Information Specialists' Sub-Group

JCVI – Joint Committee on Vaccinations and Immunisations

JE – Japanese Encephalitis vaccine

LA – local authority

LMIC – low/middle-income countries

LSOA – Lower-layer Super Output Area

MA – meta-analysis

MAR – missing at Random

MCV – Measles-containing vaccine

MenB – Meningitis B

MenC – Meningitis C

MMR – Measles, Mumps and Rubella vaccine

MMR2 – Measles, Mumps and Rubella vaccine, second dose

MPs – members of parliament

mRNAs – messenger ribonucleic acid

Na – Narrative analysis

NE – North East of England

NECS – North East of England Care System Support

NHS – National Health Service

NHSE – National Health Service England

NHSE PHP – National Health Service England Public Health Programmes

NIHR ARC NENC – National Institute for Health and Care Research, Applied Research Collaboration, North East and North Cumbria

NW – North West of England

OHID – Office for Health Improvement and Disparities

OPV – oral Poliovirus

OR – Odds ratios

PBE – personal belief exemptions

PCV – Pneumococcal vaccine

PECOS – population, exposure, comparator, outcome, and study design

PHE – Public Health England

PICOS – population, intervention, comparator, outcome, and study design

PMS – Personalised Medical Service Contracts

PRISMA-E – preferred reporting items for systematic reviews and meta-analyses, equity extension

PROGRESS+ – Place of residence, Race/ethnicity/culture/language, Occupation, Gender/sex, Religion, Education, Socioeconomic status, Social capital, and + Personal characteristics associated with discrimination (e.g. age/disability), features of relationships (e.g. smoking parents, excluded from school), and time-dependent relationships (e.g. leaving the hospital, respite care, other instances where a person may be temporarily at a disadvantage).

PROSPERO – International Prospective Register of Systematic Reviews

QOF – quality outcome framework

REC – Research Ethics Committee

RoB – risk of bias

Rota – Rotavirus

RVC – European Regional Verification Commission for Measles and Rubella Elimination

SAGE – Strategic Advisory Group of Experts on Immunization

SARS CoV-2 – Severe Acute Respiratory Syndrome, Coronavirus-2

SD – standard deviation

SES – socioeconomic status

SNOMED – Systematised Nomenclature of Medicine

SWiM – synthesis without meta-analysis

TAPER – Deep End Project: primary care Professionals’ Experience of Reducing opioid and gabapentinoid prescribing in socioeconomically disadvantaged communities in the North East of England

UK – United Kingdom

UKHSA – United Kingdom Health Security Agency

US – United States

UTLA – upper-tier local authorities

VHDM – Vaccine Hesitancy Determinants Matrix

VLPs – virus-like particles

VPDs – vaccine preventable diseases

w/e – week ending

WHO – World Health Organisation

YF – Yellow Fever vaccine

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Chapter 1. Introduction and Background

1.1. Background

1.1.1. *The COVID-19 pandemic*

“For me, I’ve never been one to say no to a vaccine. Its part and parcel—as a child you are given various vaccines, and you don’t necessarily have a choice, but then when you have your boosters, you just go ahead and do it and to me that’s part of normal life. [Participant 10, Male, 40s]” (Williams et al., 2023, p. 8).

The Coronavirus pandemic of 2019 (COVID-19) refocused global attention on the topic of vaccination. The above quote is sourced from a qualitative interview study of UK adults exploring their barriers and facilitators to receiving the COVID-19 vaccine. The participant references several important aspects of the vaccination uptake discourse that will be explored throughout this chapter and thesis.

In December 2019, the novel coronavirus was detected in Wuhan, China. The disease (SARS-CoV-2, Severe Acute Respiratory Syndrome-Coronavirus-2) presents as viral pneumonia and is primarily spread through respiratory droplets via close contact with infected persons (Siddiqui, Alhamdi and Alghamdi, 2022). It is estimated that within three months following initial detection, the virus had spread to 114 countries (minimum) and caused over 4,000 deaths (Park, 2020). On 11th March, the Director General of the World Health Organisation (WHO), Dr Tedros Adhanom Ghebreyesus, declared a global pandemic (World Health Organization, 2020). A global pandemic is an outbreak of disease that involves multiple countries and continents (Elmore et al., 2020a).

Various safety measures were employed to reduce transmission, such as limiting movement, introducing social distancing rules, and implementing the wearing of face coverings. These were enforced differently across the globe; some were recommendations, whereas others incurred legal repercussions if not adhered to. Safety measures were met with varying degrees of compliance. Over time, populations began to experience pandemic “*fatigue*”, which contributed to an overall decrease in adherence (Crane et al., 2021; Petherick, 2021). In 2021, the UK government adopted the phrase

“Stay home, protect the NHS, save lives” (Cairney, 2021). There was an emphasis on avoiding healthcare environments for non-life-threatening concerns; all areas were affected by cancellations, delays, and disruptions as staff and resources were diverted to pandemic efforts (Propper, Stoye and Zaranko, 2020). Thus, developing, testing, and distributing an effective vaccine was a priority to curtail the mortality and morbidity associated with the disease and relieve the pressure on healthcare systems.

Several COVID-19 vaccines, such as AstraZeneca, Moderna, and Sputnik V, were under development. However, the first vaccine licenced for widespread use was Pfizer-BioNTech, of which the first vaccination was administered on 8th December 2020 in the UK (Watson *et al.*, 2022). The subsequent COVID-19 vaccination rollout was the most rapid in history (Glassman, Kenny and Yang, 2022). It was estimated that 14.4 million COVID-associated deaths were prevented globally between 8th December 2020 and 8th December 2021 (Watson *et al.*, 2022), the result of an estimated 8.36 billion cumulative vaccine doses administered during the same period (Our World in Data, 2024). This figure is now 13.72 billion doses as of 12th August 2024 (Our World in Data, 2024). However, this expedited process of vaccine development caused concern for some individuals regarding the rigorousness of the clinical trials and the long-term effects of vaccination (Williams *et al.*, 2023).

1.1.2. *The unequal pandemic*

While the COVID-19 pandemic impacted everyone, some groups were disproportionately affected – an “unequal pandemic” (Bambra, 2021) – that exacerbated existing inequalities within and between populations. Bambra *et al.* (2021, p. 149; Bambra, Albani and Franklin, 2021) suggest that *“increased vulnerability, susceptibility, exposure and transmission”* are the causal pathways linking existing inequalities to an increased prevalence of COVID-related adverse experiences. Research demonstrates a significant association between socioeconomic inequality and COVID-19 incidence rates and mortality (Shahbazi and Khazaei, 2020). For example, on average, a one percentage point increase in the Gini index (an indicator of income inequality within a country) was associated with a 9% increase in the hazard of having a higher COVID-19 infection rate and a 14% increase in mortality in the sample (Arbel *et al.*, 2022). The cooccurrence of

existing and pandemic inequalities is referred to as a syndemic pandemic (Bambra *et al.*, 2020; McGowan and Bambra, 2022). A syndemic is a “set of closely intertwined and mutually enhancing health problems that significantly affect the overall health status of a population within the context of a perpetuating configuration of noxious social conditions” (Singer, 2000, p. 13).

As well as increased vulnerability, susceptibility, exposure and transmission, socioeconomically disadvantaged groups were more likely to experience lower levels of COVID-19 vaccination availability and uptake. Vaccine availability inequalities were especially evident in lower- and middle-income countries; consequently, coverage was lower in these contexts (Watson *et al.*, 2022). Decreased *availability* was linked to a range of factors, such as a lower prevalence of healthcare settings to disseminate vaccines, increased difficulty accessing rural areas, and the influence of global politics (Upadhyay *et al.*, 2022). Whereas low *uptake* amongst socioeconomically disadvantaged groups was related to vaccine hesitancy (Sallam, Al-Sanafi and Sallam, 2022; Morales, Beltran and Morales, 2022) and decreased access to vaccination (Bayati *et al.*, 2022; Torres, Moreno and Rivadeneira, 2023). However, other research suggests there may be lower COVID-19 vaccination uptake amongst *advantaged* socioeconomic groups and higher uptake for *disadvantaged* socioeconomic groups in certain settings (Pouliasi *et al.*, 2023).

This represents the context in which the research detailed in this thesis was conducted. In the following section, the fundamental concepts of this thesis are explored and defined. Then, the rationale for the research is discussed, including the aims and objectives, and the contents of the proceeding chapters are outlined.

1.2. Key Concepts: Health and Health(care) Inequalities

1.2.1. The Socio-ecological Model of Health and health(care) inequalities

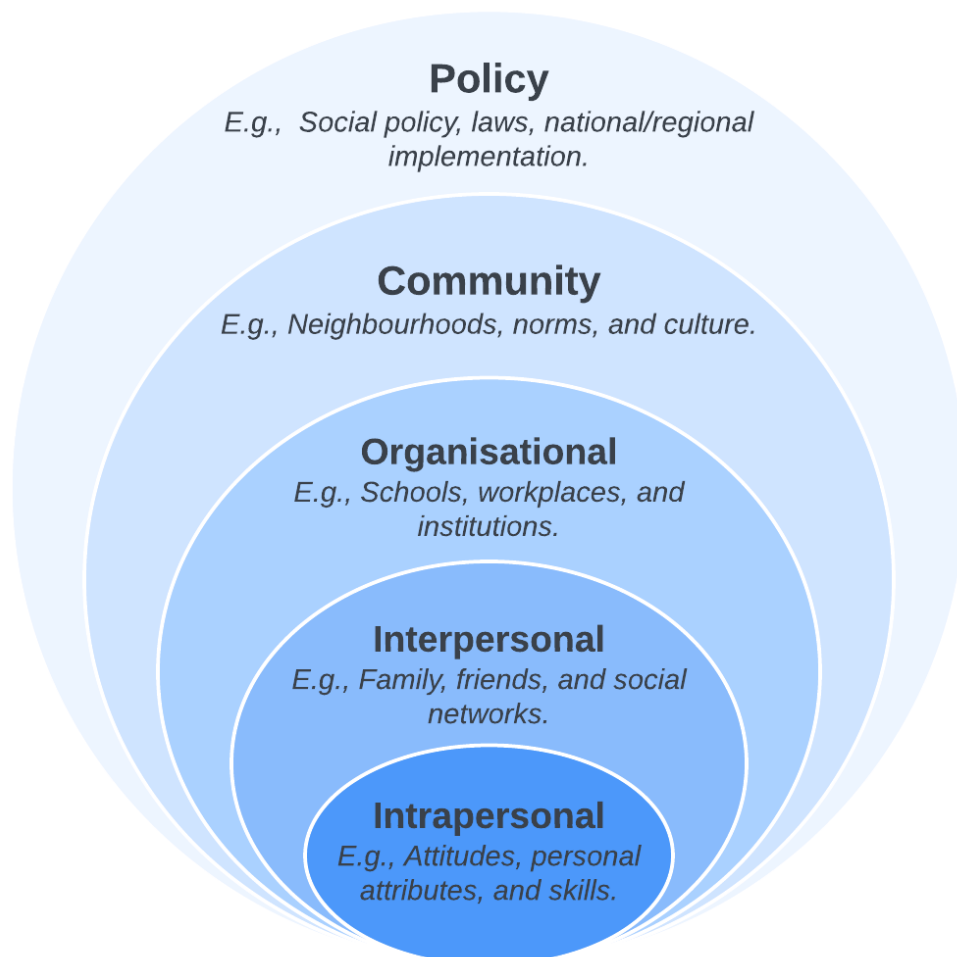
Various theories can help conceptualise the association between demography and health. One such theory is the Socio-ecological Model of Health, which stems from an ecological model by Bronfenbrenner (1977), demonstrating how human development interacts with changing environments. In 1988, McLeroy *et al.* applied this framework to health promotion interventions and suggested

“...the importance of ecological models in the social sciences is that they view behaviour as being affected by, and affecting the social environment...Thus, ecological models are systems models, but they differ from traditional systems models by viewing patterned behaviour – of individuals or aggregates – as the outcomes of interest.” (McLeroy et al., 1988, p. 55)

Subsequently, they reconceptualised the model to include five levels of influences: (1) intrapersonal, (2) interpersonal, (3) organisational/institutional, (4) community, and (5) policy (McLeroy et al., 1988). Often, the model is presented in graphical form, as displayed in Figure 1.1.

Figure 1.1

Socioecological model of health; the five levels including examples.



The model emphasises how health-related choices and behaviours are determined and influenced by factors often beyond their control. Marmot and Wilkinson (2005) use the example of diet to articulate this issue; access to healthful foods is based on several factors, including food supply chains, cultural practices, accessibility, availability, and

affordability. Section 1.1.2, *The unequal pandemic*, discussed how similar factors impacted COVID-19 vaccination.

When specific individuals or groups experience adverse health experiences or outcomes, these are referred to as inequalities. Fundamentally, health inequalities are “*individual differences in health, differences in health between population groups, and differences between groups linked to wider social inequalities*” (Graham, 2007, p. 4). This definition suggests they operate on various scales, both within and between populations. Whitehead and Dahlgren (2006, p. 2) take a different but complementary approach. They define health inequalities as “*systematic, socially produced (and therefore modifiable) and unfair*”. Their phrasing frames health inequalities as non-naturally occurring phenomena and suggests they can be impacted by positive change and effective intervention. Health inequalities are a

“...consequence of progress. Not everyone gets rich at the same time, and not everyone gets immediate access to the latest life-saving measures, whether access to clean water, to vaccines, or to new drugs for preventing heart disease.” (Deaton, 2013, p. 1)

Although closely linked, health inequalities and healthcare inequalities are different concepts. Healthcare inequalities refer to “*equality of utilization, distribution according to need, equality of access, and equality of health*” (Culyer and Wagstaff, 1993, p. 431). This definition is related to other discussions of *inequalities* and *inequities*.

“...the former is simply a dimensional description employed whenever quantities are unequal, while the latter requires passing a moral judgment that the inequality is wrong.” (Arcaya, Arcaya and Subramanian, 2015, p. 2)

For instance, *unequal* access, such as more opportunities for healthcare, may be required to ensure *equal* utilisation for groups that face more barriers. In a policy context, this is referred to as proportionate universalism. Proportionate universalism states that “*health actions must be universal, not targeted, but with a scale and intensity that is proportionate to the level of disadvantage*” (Carey, Crammond and De Leeuw, 2015, p. 1). For a healthcare system to adopt a proportionate universalist stance, provision must be equitable (distributed according to need) instead of equal (irrespective of need).

As the Socio-ecological Model of Health in Figure 1.1 illustrates, health and healthcare inequalities can be caused by various mechanisms related to several factors. One of these factors is socioeconomic inequality.

1.2.2. Socioeconomic inequality in health and healthcare

Socioeconomic inequality can be a complex concept to define. However, it is generally accepted as related to one or a combination of the following concepts: occupation (employment/unemployment), income (wealth), education, deprivation (poverty), social capital and human capital, socioeconomic class, and socioeconomic status (Braveman *et al.*, 2005; Graham, 2007; Marx, Engels and McLellan, 2008; Galobardes *et al.*, 2006). Graham (2007, p. 36) suggests that socioeconomic inequality is “*both structurally imposed and socially produced, with the resulting inequalities in people’s positions woven into the fabric of their daily lives*”. Thus, society often causes and reproduces inequality based on those with limited access to, or possession of, economically-related resources (Graham, 2007; Marx, Engels and McLellan, 2008).

Fundamentally, people who experience high levels of socioeconomic disadvantage have an increased likelihood of mortality and morbidity when compared to those who experience less disadvantage (Graham, 2007; Bonaccio *et al.*, 2020). One key feature of socioeconomic inequalities is the social gradient;

“It runs from top to bottom of society, with less good standards of health at every step down the social hierarchy. Even comfortably off people somewhere in the middle tend to have poorer health than those above them.” (Michael Marmot and Wilkinson, 2005, p. 2).

As the definition suggests, it is accepted that, on the whole, individuals and populations adhere to this gradient. For instance, those of an advantaged socioeconomic position from a high-income country have lower mortality rates than those of a (relative) socioeconomic position in a low-income country (Arcaya, Arcaya and Subramanian, 2015; Graham, 2007). Often, those who are socioeconomically disadvantaged face greater difficulties accessing healthcare (Walters and Suhrcke, 2005), are more likely to delay treatment (Gordon, Booysen and Mbonigaba, 2020), and experience longer waiting times for these treatments (Moscelli *et al.*, 2018). Thus, there is evidence for both socioeconomic inequalities in health and healthcare.

1.3. Key Concepts: Vaccination

1.3.1. Preventative healthcare, vaccination and immunisation

The idealistic goal of healthcare is orientated towards prevention (Elmore *et al.*, 2020c). There are three prevention stages: the pre-disease stage, the latent disease stage, and the symptomatic disease stage (Elmore *et al.*, 2020b). Table 1.1 details these three stages, their associated levels of prevention, known as Leavell levels, and accompanying healthcare interventions (Leavell and Clark, 1958). As Table 1.1 articulates, the process begins with the mitigation of disease, considered “primary prevention”, which includes “health promotion” and “specific protection”; vaccination offers specific protection against vaccine-preventable diseases (VPDs). Vaccination aims to stimulate an immune response, which can reduce associated morbidity and mortality if the host becomes infected or prevent infection through herd immunity.

Table 1.1

Levels of prevention (Elmore *et al.*, 2020b; Leavell and Clark, 1958)

Stages of Disease and Care	Level of Prevention	Appropriate Response	Examples
Pre-disease risk factors			
No known risk factors	Primary prevention	Health promotion	Encourage healthy changes in lifestyle, nutrition, and environment
Disease susceptibility	Primary prevention	Specific protection	Recommend nutritional supplements, immunisations, and occupational and automobile safety measures
Latent Disease			
“Hidden” stage; asymptomatic disease	Secondary prevention	Screening (for populations) or case finding (for individuals in medical care)	Screening for osteoporosis by measuring bone mineral density in older women; testing bone mineral density in patients on long-term corticosteroids; treating those with low values
Symptomatic Disease			
Initial care	Tertiary prevention	Disability limitation	Institute medical or surgical treatment to limit damage from the disease and institute primary prevention measures

Subsequent care	Tertiary prevention	Rehabilitation	Identify and teach methods to reduce physical and social disability
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It is important to distinguish between “vaccine”, “vaccination”, “immunity”, and “immunisation”. The Centre for Disease Control and Prevention (CDC) (2021) provide the following definitions:

Vaccine: A preparation that is used to stimulate the body’s immune response against diseases. Vaccines are usually administered through needle injections, but some can be administered by mouth or sprayed into the nose.

Vaccination: The act of introducing a vaccine into the body to produce protection from a specific disease.

Immunisation: A process by which a person becomes protected against a disease through vaccination. This term is often used interchangeably with vaccination or inoculation.

Immunity: Protection from an infectious disease. If you are immune to a disease, you can be exposed to it without becoming infected.

Thus, *immunisation* refers to the entire process of producing *immunity* through *vaccination* with a *vaccine*. When populations exhibit high levels of immunity, this is called herd immunity.

Herd immunity: A vaccine provides herd immunity if it not only protects the immunized individual, but also prevents that person from transmitting the disease to others. This causes the prevalence of the disease organism in the population to decline (Elmore *et al.*, 2020a).

The number needed to vaccinate in a given population for a disease to achieve herd immunity can be calculated using the infection rate (R_0); 83-85% for Diphtheria and 92-94% for Measles (Hamilton, 2017). There are different types of vaccines for various vaccine-preventable diseases. The four main types currently licensed for widespread use are live-attenuated pathogens, killed (components of) pathogens or toxins, viral vectors, and mRNAs (messenger ribonucleic acid), as described in Table 1.2.

Table 1.2

Types of vaccine platforms currently licensed for widespread use and associated vaccines, informed by Hahne *et al.* (2022).

Vaccine platforms*	Examples
Live-attenuated pathogens	Live-attenuated antigens: <i>Smallpox, measles, mumps, rubella, yellow fever and oral polio</i> Live-attenuated bacteria: <i>BCG, and typhoid</i>
Killed (components of) pathogens or toxins	Killed organisms: <i>Inactivated polio, rabies, Hepatitis A and whole-cell pertussis</i> Subunits of organisms (polysaccharides, proteins or glycoproteins): <i>Meningococcal, pneumococcal and Haemophilus influenzae type b, acellular pertussis, and hepatitis B</i> Virus-like particles (VLPs): <i>Human papillomavirus</i> Toxins secreted by organisms: <i>Diphtheria and tetanus</i>
Viral vectors	Genetically engineered antigen coding: <i>Ebola</i>
mRNAs (messenger ribonucleic acid)	Genetically engineered antigen coding: <i>COVID-19</i>
*Currently licenced for widespread use.	

In addition to rigorous development procedures, vaccines must endure three main experimental phases of clinical trials before being licenced. At each stage, groups with different demographics are used to assess the immune response, potential side effects, and overall safety (Lockhart and Gruber, 2022; Hahné, Farrington and Bollaerts, 2022).

After licencing, health governing bodies may utilise them in their vaccination schedules. These are referred to as routine vaccinations. Vaccination schedules are a series of mandatory or recommended vaccinations a health governing body offers their population. The COVID-19 vaccine is an example of a pandemic vaccination, although it has since been integrated into many schedules. The WHO recommends which vaccines should be offered as part of vaccination schedules, including how many doses and at what ages they should be administered. These recommendations can be viewed in Appendix 1.1. However, the vaccine-preventable diseases and the brand of vaccine included are contingent on various factors such as disease prevalence, healthcare infrastructure, vaccination programme funding and cost-effectiveness (Hahné, Farrington and Bollaerts, 2022).

1.3.2. Vaccination success

When discussing the success of vaccination, it is important to distinguish between the terms “uptake” and “coverage”. MacDonald *et al.* (2019) suggests the following definitions:

Coverage refers to the number vaccinated divided by the target population, often represented as a proportion.

Uptake refers to the raw number of individuals vaccinated.

Vaccinations are regarded as one of the most cost-effective medical interventions, as they can successfully impact health outcomes by reducing the morbidity and mortality associated with vaccine-preventable diseases (World Health Organization, 2024d). Disease incidences can be significantly reduced or even eradicated if high levels of vaccination uptake are achieved and maintained. Subsequently, the WHO (2024d) states vaccination is an “*indisputable human right*” and should be readily available to the entire global population. Currently, there are 20 effective vaccines which prevent 3.5 to 5 million deaths per year (World Health Organization, 2024d). Despite this, the availability of vaccinations is far from universal. For instance, the Human Papillomavirus vaccine (HPV) is more commonly offered as part of the vaccination schedule in high-income countries than in lower-income countries despite 87% to 80% of deaths from cervical cancer occurring in lower- and middle-income countries (2023). There are several reasons for this, as discussed in the previous section.

In recent years, global vaccination uptake has been declining. Despite saving an estimated 57 million child deaths between 2000 and 2022, in 2022, the proportion of children vaccinated against Measles by their first birthday was 83%, the lowest since 2008 (World Health Organization, 2024a). This could be related to various factors, such as the residual effects of COVID-19, or increasing vaccine hesitancy.

1.3.3. Vaccine hesitancy

Vaccine hesitancy

“...refers to delay in acceptance or refusal of vaccination despite availability of vaccination services. Vaccine hesitancy is complex and context specific, varying across time, place and vaccines. It is influenced by factors such as complacency, convenience and confidence.” (MacDonald, 2015, p. 4161).

Vaccine hesitancy operates on a continuum:

- Individuals who view vaccines and vaccination positively, and thus accept them all when offered with no concerns.
- Individuals who view vaccines and vaccination sceptically, and thus delay or decline some or all vaccinations when offered due to their concerns or beliefs – classified as **vaccine-hesitant**.
- Individuals who view vaccines and vaccination negatively, and thus decline all vaccinations when offered due to their concerns or beliefs – classified as **“anti-vaxxers”**.

The majority of the global population resides somewhere between vaccine acceptance and vaccine-hesitant, with a small minority classed as “anti-vax” (MacDonald, 2015). There are different ways of conceptualising vaccine hesitancy. One of these is the Vaccine Hesitancy Determinants Matrix (VHDM) (MacDonald, 2015), which collates various factors into three groups: contextual influences, individual and group influences, and vaccine/vaccination-specific issues. Definitions of each category and some examples of barriers can be seen in Table 1.3.

Table 1.3

Vaccine Hesitancy Determinants Matrix (MacDonald, 2015).

Influences/issues	Examples
Contextual Influences <i>Influences arising due to historic, socio-cultural, environmental, health system/institutional, economic or political factors.</i>	Communication and media environment
	Influential leaders, immunization program gatekeepers and anti- or pro-vaccination lobbies
	Historical Influences
	Religion/culture/gender/socio-economic
	Politics/policies
	Geographic barriers
	Perception of the pharmaceutical industry
Individual and Group Influences <i>Influences arising from personal perception of the vaccine or influences of the social/peer environment.</i>	Personal, family and/or community members' experience with vaccination, including pain
	Beliefs, attitudes about health and prevention
	Knowledge/awareness
	Health system and providers-trust and personal experience
	Risk/benefit (perceived, heuristic)
	Immunisation as a social norm vs. not needed/harmful
Vaccine or Vaccination-specific Issues <i>Directly related to vaccine or vaccination.</i>	Risk/ Benefit (epidemiological and scientific evidence)
	Introduction of a new vaccine or new formulation or a new recommendation for an existing vaccine
	Mode of administration
	Design of vaccination program/Mode of delivery (E.g., routine program or mass vaccination campaign)
	Reliability and/or source of supply of vaccine and/or vaccination equipment
	Vaccination schedule
	Costs
	The strength of the recommendation and/or knowledge base and/or attitude of healthcare professionals

1.3.4. The MMR crisis 1998

One notable event regarding the impact of vaccine hesitancy on uptake was the measles, mumps, and rubella (MMR) crisis of 1998. The crisis originated from an article published by Andrew Wakefield (RETRACTED 1998) describing a study exploring 12 children admitted to a paediatric gastroenterology department after reporting a loss of skills, such as language, and stomach issues. The children underwent a series of assessments which “identified associated gastrointestinal disease and developmental regression in a group of previously normal children, which was generally associated in time with possible

environmental triggers” (RETRACTED Wakefield *et al.*, 1998, p. 636). The “*environmental triggers*” were linked by the parents or the child’s general practitioner (GP) to receiving the MMR vaccine, and the “*developmental regression*” was diagnosed as autism spectrum disorder. Wakefield *et al.* stated they “*did not prove an association between the measles, mumps, and rubella vaccine and the syndrome described*”, but suggested that more evidence would become apparent if the UK implemented it in their vaccination schedule (RETRACTED Wakefield *et al.*, 1998, p. 641).

However, undisclosed conflicts of interest regarding funding were later identified (Eggertson, 2010), as well as ethical issues concerning research committee approval and biased participant selection methods (Editors of the Lancet, 2010). These issues can affect the reliability of the findings. Consequently, the Lancet retracted the article in 2010, and Wakefield was found guilty of ethical violations and scientific misrepresentation (Rao and Andrade, 2011). Irrespective of the retraction, the article had already been the subject of discussion by multiple media outlets, leading to widespread exposure of the narrative that MMR vaccine uptake is associated with autism spectrum disorder. The academic community made efforts to prove that no such association exists. A time trend analysis by Kaye *et al.* (2001) identified no correlation between incidences of autism diagnoses and MMR vaccination uptake from 1988 to 1993.

The effect of the Wakefield article was far-reaching. There is evidence to suggest an increase in vaccine hesitancy, a decrease in vaccine uptake, and a subsequent increase in Measles outbreaks (Li, Stroud and Jamieson, 2017; Owens, 2002; Burgess, Burgess and Leask, 2006). The impact expanded beyond Measles, with “spillover” effects contributing to a decrease in the uptake of other childhood vaccinations (Anderberg, Chevalier and Wadsworth, 2011). There was an identified rise of 70 MMR injury claims per month in the US, associated with an increase in the negative media attention (Motta and Stecula, 2021). The concerns surrounding the MMR vaccine have been difficult to address (Li, Stroud and Jamieson, 2017), and recent research suggests that parents are still concerned about the link to autism (Toll and Li, 2021).

1.4. Conclusion

1.4.1. *The rationale for research*

To summarise, Chapter 1 has discussed the impact of COVID-19 on socioeconomic inequalities in health and healthcare. There is the potential for spillover effects of increased negative public attention on vaccination and the uptake of other vaccines. It has also been suggested that global routine vaccination uptake is declining. However, the interaction between these issues is unclear. A study conducted in Liverpool, UK, exploring a measles outbreak in 2012–13, identified that deprived neighbourhoods had the highest proportion of disease-susceptible children due to under-immunisation (Keenan *et al.*, 2017). These pockets of low uptake can, in turn, exacerbate socioeconomic inequalities, as discussed in Section 1.2.2, *Socioeconomic inequality in health and healthcare*. Therefore, understanding this issue is both timely and important.

The aim of this thesis is as follows:

Aim – To understand and map the narrative and state of socioeconomic inequalities in vaccination uptake in a post-COVID-19 era.

To address this aim, there are four main objectives:

Objective 1 – Using evidence synthesis, examine whether there are socioeconomic inequalities in vaccine uptake, summarise the contexts in which they exist, and identify any mechanisms that could potentially explain these inequalities.

Objective 2 – Quantitatively analyse whether there has been a change in socioeconomic inequalities in vaccination uptake in England associated with the COVID-19 pandemic.

Objective 3 – Qualitatively explore the landscape of delivering, commissioning, supporting, and monitoring vaccination programmes with a specific focus on areas of high socioeconomic deprivation.

Objective 4 – Connect the findings from the umbrella review, quantitative analysis, and qualitative study to provide a comprehensive overview of socioeconomic inequalities in vaccination uptake on a global, national, and regional level.

The project was funded by the National Institute for Health and Care Research (NIHR) Applied Research Collaboration (ARC) North East and North Cumbria (NENC) and, therefore, seeks to produce findings relevant to policy and practice in England. This project comprised two components: (1) an umbrella systematic review of global socioeconomic inequalities in routine vaccination uptake (Objective 1), and (2) a mixed methods study in England focused on childhood vaccinations. The quantitative element used piecewise regressions to analyse the effects of COVID-19 and socioeconomic deprivation on MMR and pre-school booster uptake (Objective 2). The qualitative aspect involved interviews with professionals commissioning, supporting, and monitoring the childhood vaccination programme in the North East of England, focusing on areas of high socioeconomic deprivation (Objective 3). The integration of mixed methods study took a sequential explanatory approach, meaning that the quantitative analysis findings guided the qualitative methods (Objective 4).

1.4.2. Thesis overview

Chapter 2 addresses Objective 1 using a global umbrella review of socioeconomic inequalities in routine vaccination uptake. Firstly, the strengths and limitations of relevant existing systematic reviews are discussed. Then, the methods are outlined, including how the results were narratively synthesised, aided by a patient-centred access to vaccination framework. Afterwards, the search results and discuss the review's key findings are presented. These findings are then contextualised before stating the limitations of the approach and suggestions for future research.

Chapter 3 explains how the umbrella review findings will shape the rest of the thesis as applied to England. Next, the appropriateness and usefulness of narrowing the scope to childhood vaccinations are argued. Building on this information, a literature review is performed to identify relevant studies and where the research is currently lacking and, in

so doing, justify the need for further study. Next, the issues of ontology and epistemology are addressed. The patient-centred access to vaccination framework is adapted, as informed by the umbrella review and the Socio-ecological Model of Health, before explaining how this will be utilised further in Chapter 6. Lastly, reflexivity is discussed, and the mixed methods model employed to integrate the quantitative and qualitative components is described. Chapter 3, therefore, aims to establish a solid literary foundation on which the empirical Chapters 4 and 5 are built.

Chapter 4 addresses Objective 2 and represents the quantitative component of the mixed methods study: a piecewise regression analysis of the interaction between deprivation and COVID-19 on area-level childhood vaccination uptake. First, the different types of data available are discussed before outlining the operationalisation of the variables used in the analysis. Afterwards, the statistical methods, hypotheses, and model specifications are presented. An exploratory analysis is then performed to justify a narrowed focus on two childhood vaccines. Following this, the results of the main analyses are presented, including various tests of robustness. To conclude, the findings in relation to the hypotheses are summarised, including the limitations of the approach, and discuss the implications of these findings for the qualitative interview study.

Chapter 5 presents the methodological approach and findings of a qualitative interview study exploring the delivery of the childhood vaccination programme in areas of high socioeconomic deprivation in this context. In doing so, this addresses the third thesis objective. This chapter first presents a brief overview of the interview setting and the research questions before detailing the study design. Then, the sampling frame and recruitment process are discussed, before outlining the ethical approval process. Afterwards, the interview guide, transcript coding, and framework analysis are explored. The findings are then presented. An overview of the interview process is provided, including anonymised participant information. Then, the identified themes are stated before proceeding to the in-depth analysis. Finally, the research questions are addressed, followed by the methodological limitations.

Chapter 6 brings together the findings of the umbrella review and the mixed methods study, thus addressing Objective 4. It first provides a succinct overview of the main

findings from each empirical element. Afterwards, the findings of the umbrella review and quantitative and qualitative studies are integrated and contextualised using the wider literature. The final version of the patient-centred access to vaccination framework is presented, now grounded in the primary data. Following this, the overall message of the thesis is discussed, including the implications of the integrated findings. To conclude, recommendations are made, and methodological strengths and limitations outlined, before suggestions for future research and concluding remarks are provided.

Chapter 2. **Socioeconomic Inequalities in Vaccination Uptake: A Global Umbrella Review**

2.1. Introduction

2.1.1. Chapter overview

The methods and findings presented in this chapter have been published in the following papers:

Sacre, A., Bambra, C., Wildman, J. M., Thomson, K., Sowden, S., & Todd, A. (2022). Socioeconomic Inequalities and Vaccine Uptake: An Umbrella Review Protocol. *International Journal of Environmental Research and Public Health*, 19(18), 11172. doi.org/10.3390/ijerph191811172

Sacre, A., Bambra, C., Wildman, J.M., Thomson, K., Bennett, N., Sowden, S., & Todd, A. (2023). Socioeconomic inequalities in vaccine uptake: A global umbrella review. *PLOS ONE*, 18(12), e0294688. doi.org/10.1371/journal.pone.0294688

Chapter 1 presented an overview of health and healthcare inequality, socioeconomic inequality, and vaccination. However, it did not investigate the intersection of these concepts in detail. Chapter 2, therefore, addresses Objective 1, as follows:

Objective 1 – Using evidence synthesis, examine whether there are socioeconomic inequalities in vaccine uptake, summarise the contexts in which they exist, and identify any mechanisms that could potentially explain these inequalities.

Firstly, the strengths and limitations of relevant existing systematic reviews are discussed. Then, the methods are outlined, including how the results were narratively synthesised, aided by a patient-centred access to vaccination framework. Afterwards, the search results and discuss the review's key findings are presented. These findings are then contextualised before stating the limitations of the approach and suggestions for future research.

2.2. Literature Review

2.2.1. Mapping relevant systematic reviews

One of the most notable systematic reviews investigating factors associated with vaccination uptake was published by Larson *et al.* (2014). The review was commissioned by the Strategic Advisory Group of Experts on Immunization (SAGE) Working Group (World Health Organization, 2024b) and explores childhood vaccine hesitancy from a global perspective. It provides a valuable overview of the discourse and reflects its complexities. However, their conclusions are conflicting and complex, as summarised in Table 2.1. Advantaged and disadvantaged income/socioeconomic status can act as both barriers and promoters to vaccination uptake.

Table 2.1

Summary of systematic review findings by Larson *et al.* (2014).

	Barrier Factors preventing or contributing to low vaccination uptake.	Promoter Factors encouraging or positively contributing to vaccination uptake.
Disadvantaged income or socioeconomic status	USA (n = 1) (Wu <i>et al.</i> , 2008) Nigeria (n = 1) (Antai, 2012)	Nigeria (n = 1) (Antai, 2009) Bangladesh (n = 1) (Rahman and Obaida-Nasrin, 2010)
Advantaged income or socioeconomic status	USA (n = 1) (Wei <i>et al.</i> , 2009)	Burkina Faso (n = 2) (Sanou <i>et al.</i> , 2009; Sia <i>et al.</i> , 2009) India (n = 1) (Patra, 2012) Bangladesh (n = 1) (Rahman and Obaida-Nasrin, 2010)
Disadvantaged education	Nigeria (n = 4) (Antai, 2012; Antai, 2009; Babalola, 2011; Oladokun, Adedokun and Lawoyin, 2010) India (n = 1) (Kumar, Aggarwal and Gomber, 2010; Patel and Pandit, 2011) China (n = 1) (Wang, 2007) Kyrgyzstan (n = 1) (Akmatov <i>et al.</i> , 2009) USA (n = 1) (Stockwell <i>et al.</i> , 2011) DR Congo (n = 1) (Mapatano <i>et al.</i> , 2008)	USA (n = 1) (Kim <i>et al.</i> , 2007)

Advantaged education	China (n = 1) (Zhang <i>et al.</i> , 2011) Lebanon (n = 1) (Sinno <i>et al.</i> , 2009) Israel (n = 1) (Muhsen <i>et al.</i> , 2012) Bangladesh (n = 1) (Rahman and Obaida-Nasrin, 2010) USA (n = 1) (Wei <i>et al.</i> , 2009) DR Congo (n = 1) (Mapatano <i>et al.</i> , 2008)	India (n = 6) (Patra, 2012; Kumar, Aggarwal and Gomber, 2010; Phukan, Barman and Mahanta, 2009; Chhabra <i>et al.</i> , 2007; Rammohan, Awofeso and Fernandez, 2012; Vikram, Vanneman R Fau - Desai and Desai, 2021) Greece (n = 1) (Danis <i>et al.</i> , 2010) The Netherlands (n = 1) (Uwemedimo <i>et al.</i> , 2012) Nigeria (n = 1) (Oladokun, Lawoyin To Fau - Adedokun and Adedokun, 2009) Pakistan (n = 2) (Mitchell <i>et al.</i> , 2009; Siddiqi <i>et al.</i> , 2010)
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Another systematic review suggests that parents from advantaged socioeconomic groups in Germany and the United Kingdom (UK) have lower uptake of the Measles, Mumps and Rubella (MMR) vaccine than their disadvantaged counterparts (Bocquier *et al.*, 2017). These examples demonstrate that vaccination uptake may not follow a clear socioeconomic gradient, as discussed in Section 1.2.2, *Socioeconomic inequality in health and healthcare*. What is not clear is the prevalence of this finding and whether it is restricted to a specific context. A systematic review exploring the uptake of the MMR and Diphtheria-Tetanus-Pertussis-containing (DTaP) vaccines amongst infants and pre-school children in Europe and Australia (Arat *et al.*, 2019). The authors concluded that socioeconomic differences in uptake were only evident in non-hierarchical primary care organisations without well-baby clinics. To explore this further, an umbrella review, or overview of reviews, is more appropriate than a standard systematic review. Umbrella reviews are useful for synthesising large bodies of literature, analysing multiple interventions, and providing a clear and concise summary of a given topic (Pollock *et al.*, 2022). Instead of synthesising primary studies, umbrella reviews use systematic reviews as their unit of analysis.

Additionally, existing systematic reviews lack clarity in defining their socioeconomic measures. For instance, in the example of Larson *et al.* (2014), “income” and “socioeconomic status” are used interchangeably. Are authors referring to income or a

more broad, composite measure? This makes it difficult for professionals in vaccination policy and delivery to understand how their population may be impacted. An umbrella review could map these definitions and the associated effect on vaccination uptake. In this thesis, the term “socioeconomic position” is used to refer to economically related factors. This is because the more common “*socioeconomic status*” “*blurs distinctions between two different aspects of socioeconomic position: (a) actual resources, and (b) status, meaning prestige- or rank-related characteristics*” (Krieger, Williams and Moss, 1997, p. 346; Galobardes *et al.*, 2006).

2.2.2. Mechanisms

One means of exploring how and why the association between socioeconomic position and vaccination uptake may exist is through mechanisms. Mechanisms are defined as a “*process in which a causal variable of interest, i.e., a treatment variable, influences an outcome*” (Imai *et al.*, 2011, p. 765). They are likely to vary depending on various factors, such as the socioeconomic measure and the geographical context. For instance, in the UK, vaccinations are provided by a national healthcare system funded through general taxation, meaning that whilst there may be indirect healthcare access costs, there are no direct “out-of-pocket payments” (World Health Organization, 1998). In contrast, the United States (US) healthcare system is primarily market-driven, and access to vaccination is chiefly reliant on insurance funded through income or provided by employers unless eligible for government assistance (Sun, 2019). In this example, both the socioeconomic measure and the subsequent mechanism would differ. In the US, for instance, occupation may be more relevant to vaccination uptake than in the UK because of its connection to health insurance. In their systematic review, Fisher *et al.* (2013) found that women in the US without health insurance were less likely to be vaccinated against the Human Papillomavirus Vaccine (HPV). This demonstrates the importance of explicitly defining the measure of socioeconomic position and exploring the mechanisms by which it may be associated with vaccination uptake. Nevertheless, it is uncommon for systematic reviews to comment on mechanisms, and if they do, they are often described only in the discussion section or mentioned briefly. Glymour *et al.* (2015) suggests this is

a common limitation of research exploring socioeconomic inequalities which this umbrella review sought to address in the context of vaccination uptake.

Research suggests conceptual frameworks and logic models can help to synthesise diverse systematic review data (Baxter *et al.*, 2010). An umbrella review by Kaufman *et al.* (2021) synthesised evidence on parent-level barriers to childhood vaccination uptake. The authors provided a detailed overview of the literature and produced a framework to conceptualise the barriers identified. The framework is presented as a table, much like the Vaccine Hesitancy Determinants Matrix (VHDM) discussed in Section 1.3.3, *Vaccine hesitancy*. While useful, they do not visually acknowledge vaccination uptake as a process, and the information is presented as lengthy text. This can make it difficult for professionals involved in vaccination programmes who require an accessible, concise overview of the existing evidence. The umbrella review sought to address this shortfall through the development of a patient-centred access to vaccination framework.

To my knowledge, no published umbrella reviews synthesise the global body of literature on socioeconomic inequalities and vaccination uptake across various vaccines, geographical locations, and measures of socioeconomic position at the level of an umbrella review. Nor has this been performed in combination with an exploration of the mechanisms that may explain the association to inform the development of a conceptual framework.

2.2.3. Summary

Understanding the association between socioeconomic inequalities and uptake is especially pertinent when considering the recent global decline in vaccination (discussed in Section 1.3.2, *Vaccination success*) and the potential impact of COVID-19 (discussed in Section 1.1.2, *The unequal pandemic*). Many published umbrella reviews focus on interventions to improve uptake (Scalia, Durand and Elwyn, 2022; Frew and Lutz, 2017; Norman, Kletter and Dumville, 2024), and do not adequately explore the role of socioeconomic inequalities, demonstrating the uniqueness of the approach.

Collating the existing evidence on socioeconomic inequalities in vaccination uptake may help programme commissioners and providers to ascertain in which specific circumstances the association may exist and, equally, when they do not. Considering this review utilised the global literature, the findings could be used to compare the state of uptake across regions or countries, prompting further investigation or highlighting the need for intervention. For the academic community, and for the purpose of this thesis, the synthesis process could identify understudied or overstudied areas to guide further research. This review, therefore, aimed to: (1) examine whether there are socioeconomic inequalities in vaccination uptake and summarise the contexts in which they exist and (2) identify any mechanisms that could potentially explain these inequalities according to systematic review authors.

2.3. Methods: Searching and Screening

2.3.1. Research questions

The review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) (ID: CRD42022334223), and a protocol was published (Sacre *et al.*, 2022). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Equity extension (PRISMA-E) guidelines, developed for systematic reviews with an equity focus (Welch *et al.*, 2012), was utilised. A completed PRISMA-E checklist can be viewed in Appendix 2.1.

The research questions were as follows:

Research Question 1: Are there socioeconomic inequalities in vaccination uptake?

Research Question 2: What are the mechanisms identified to explain such socioeconomic inequalities in vaccination uptake?

The research questions were broad to capture all relevant systematic reviews and adequately map the discourses' complexity.

2.3.2. Defining an umbrella review

Umbrella reviews represent the highest level of evidence synthesis. They are awarded this title by “*compiling evidence from multiple reviews into one accessible usable document*” (Grant and Booth, 2009, p. 95). The terms “overview of reviews”, “review of reviews” and “umbrella review” are used (Grant and Booth, 2009) interchangeably in the literature. They differ from standard systematic reviews in that the unit of analysis is systematic reviews, as opposed to primary studies. Umbrella reviews are increasing in prevalence, but published guidance is lacking, meaning each researcher often approaches them differently (Pollock *et al.*, 2016). Cochrane provides one chapter on overviews of reviews in their systematic review handbook, which informed the approach (Pollock *et al.*, 2022).

There are five fundamentals of an umbrella review (Pollock *et al.*, 2022; Pollock *et al.*, 2016):

1. Contains a clearly formulated objective designed to answer a specific research question, typically about a healthcare intervention.
2. Intends to search for and include only systematic reviews (with or without meta-analyses).
3. Uses explicit and reproducible methods to identify multiple systematic reviews that meet the overview of reviews’ inclusion criteria and assess the quality/risk of bias of these systematic reviews.
4. Intends to collect, analyse, and present the following data from included systematic reviews: descriptive characteristics of the systematic reviews and their included primary studies; risk of bias of primary studies; quantitative outcome data; and certainty of evidence for pre-defined, clinical important outcomes.
5. Discusses findings as they relate to the purpose, objective(s), and specific research question(s) of the overview of reviews, including: a summary of main results, overall completeness and applicability of evidence, quality of evidence, potential biases in the overview process, and agreements and/or disagreements with other studies and/or reviews.

There are drawbacks to conducting an umbrella review. One of the main issues relates to the fact that an umbrella review is the second level of abstraction; the first is the synthesis of primary studies into systematic reviews, and the second is systematic reviews into an umbrella review. Details are lost in this process, and there is a reliance on systematic review authors interpreting the results of the included primary studies accurately. If their interpretation is inaccurate, this can negatively impact the legitimacy of the umbrella review's synthesis. A second limitation linked to the accuracy of included systematic reviews is the appropriateness of all primary studies (Pollock *et al.*, 2022). Systematic reviews with broad inclusion criteria risk including primary studies that may be irrelevant to the umbrella review. If this is a significant concern, conducting a large systematic review instead of an umbrella review may be more appropriate. The third limitation of an umbrella review is the possibility that recently published relevant primary studies will not be included because they have not yet been synthesised into a systematic review (Pollock *et al.*, 2022). This means that important, recent evidence may not be captured.

2.3.3. Inclusion and exclusion criteria

Similar to the research questions, the inclusion criteria were deliberately broad to ensure that all relevant reviews were identified. The criteria were conceptualised using PECOS (Population, Exposure, Comparison, Outcome, Study Design) and are outlined below:

Population: General populations, including demographic sub-populations. All countries.

Exposure: Advantaged socioeconomic groups, according to one of the following indicators: education, income, occupation/employment, or measures of area-level deprivation/poverty (E.g., the English Indices of Multiple Deprivation (IMD)). Any operationalisation (E.g., binary or continuous measures).

The PROGRESS+ framework (O'Neill *et al.*, 2014), and common definitions of socioeconomic status (Braveman *et al.*, 2005; Graham, 2007), informed the choice of eligible socioeconomic position measures. The **PROGRESS+** framework identifies eleven determinants: **P**lace of residence, **R**ace/ethnicity/culture/language,

Occupation, **G**ender/sex, **R**eligion, **E**ducation, **S**ocioeconomic status (SES), **S**ocial capital, and **+** Personal characteristics associated with discrimination (e.g. age/disability), features of relationships (e.g. smoking parents, excluded from school), and time-dependent relationships (e.g. leaving the hospital, respite care, other instances where a person may be temporarily at a disadvantage). **PROGRESS+** is used as a conceptualisation tool in equity research developed by Cochrane Methods (O'Neill *et al.*, 2014; Cochrane Methods, 2024). Education, income, occupation/employment, and measures of area-level deprivation/poverty were selected for easier quantification.

Sections 1.2.2, *Socioeconomic inequality in health and healthcare*, and 2.2.1, *Mapping relevant systematic reviews*, demonstrated the complexity of defining and operationalising socioeconomic position. This can be more challenging if difficult-to-quantify measures, such as social and human capital, are included. This is referred to because this review did not include caste as an eligible measure of socioeconomic position. Fundamentally, caste is a means of segmenting Indian society based on various factors, such as occupation, race, and inherited familial status (Borooah, 2005; Goghari and Kusi, 2023). However, Goghari and Kusi (2023) suggest that it is much more complex. Due to this complexity, caste was not included as an eligible indicator.

Comparison: Disadvantaged socioeconomic groups, according to one of the following indicators: education, income, occupation/employment, or measures of area-level deprivation/poverty (E.g., the English Indices of Multiple Deprivation (IMD)). Any operationalisation (E.g., binary or continuous measures).

Outcome: Variation in the rate (uptake) or proportion of a target population (coverage) that has been vaccinated. Eligible vaccines were those labelled by the World Health Organization (WHO) as universally recommended routine vaccinations (World Health, 2021) (see Appendix 1.1 for more information), such as BCG (Tuberculosis), Hepatitis B (Hep B), Polio (IPV/OPV), DTP-containing (Diphtheria, Tetanus and Pertussis) vaccine, Hib (Haemophilus influenzae type b), PCV (Pneumococcal), Rotavirus, Measles, Rubella, and HPV. Studies focusing on influenza and Coronavirus were also eligible for inclusion to account for reviews published in response to the COVID-19 pandemic. Eligible

measures of uptake or coverage were initiation and/or completion of multi-dose individual vaccines or vaccination schedules (where uptake or coverage is measured by the initiation/completion of several different vaccines, some with and without multiple doses).

Study Design: Only systematic reviews synthesising quantitative or qualitative studies were included. The quantitative reviews did not have to include a meta-analysis. This approach was taken to capture all relevant information, regardless of synthesis method. A systematic review was classified as such if it met four of the following criteria, as outlined by the Database of Abstracts of Reviews of Effects (DARE) (Centre for Reviews and Dissemination, 2014):

Were inclusion/exclusion criteria reported?

Was the search adequate?

Were the included studies synthesised?

Was the quality of the included studies assessed?

Are sufficient details about the individual included studies presented?

There were no language restrictions, and any potentially relevant abstracts and titles were translated using translation tools. A publication date range from 2011 to September 2022 (present-day – at the time the searches were performed). Searching for articles published after 2011 captures relevant vaccination policy changes made as a result of the World Health Organisation’s (WHO) “*Global Vaccine Action Plan 2011-2020*” report, which outlined the updated guidance on improving uptake (World Health Organization, 2013). As this is a global umbrella review, and the WHO is a global institution, this report is relevant to all countries. More detailed inclusion and exclusion criteria can be viewed in Appendix 2.2.

2.3.4. Search strategy and pilot searches

The eligibility criteria were translated into a search strategy. As the review focused on the general population, it did not include population-specific terminology so as not to restrict the results. The search strategies of seven relevant systematic reviews were utilised to ensure all appropriate terms were included (Arat *et al.*, 2019; de Casadevante, Gil Cuesta

and Cantarero-Arévalo, 2015; Fisher *et al.*, 2013; Gallagher *et al.*, 2016; Tabacchi *et al.*, 2016; Forshaw *et al.*, 2017; Bocquier *et al.*, 2017).

The search strategy was developed using Medline via Ovid, as outlined below:

[Exposure]

Title, Abstract, Key words=

socioeconomic or socio-economic or sociodemographic or sep or ses or class or education or lifelong learning or life-long learning or human capital or school* or literacy or academic achievement or employ* or unemploy* or occupation* or job* or work or career* or vocation or economic activity or labour market activity or isco or income or wealth or wage* or salar* or earning* or low-income or money or (inequit* or inequalit* or unequal or equal* or equit* or depriv* or poverty or impoverished or disadvantage* or gradient or gap* or disparit* or difference*) adj3 economic

[Outcome 1]

AND

Title, Abstract, Key words=

vaccine* or immunize or immunise or injection* or jab* or inoculate or (tb or tuberculosis or Hep B or Hepatitis B or diphtheria or tetanus or pertussis or whooping cough or hib or haemophilus or haemophilus influenzae type b or poliovirus or polio or poliomyelitis or pneumococcal or pneumococcus or rotavirus or measles or rubella or human papillomavirus or wart virus or influenza or flu or COVID-19 or COVID 19 or COVID19 or coronavirus or SARS-CoV-2 or SARS Cov 2 or severe acute respiratory syndrome) adj3 vaccine* or (BCG or HepB or IPV or DTP-containing or DTaP or Tdap or PCV or RV or MMR or MR or HPV or IIV or LAIV) adj3 vaccine*

[Outcome 2]

AND

Title, Abstract, Key words=

vaccination or immunization or immunisation or inoculation or uptake or coverage or rate* or accept* or hesitan* or access

[Study Design]

AND

Title, Abstract, Key words=

systematic review* or systematic literature review or systematic overview or meta analys* or metaanalys* or review

Both free-text and subject headings were used, combined with the appropriate Boolean operators and proximity identifiers. Each key term must be individually searched to identify the unique subject heading under which the database indexes relevant articles.

For example, at the time of searching (September 2022), the term “socioeconomic status” is indexed in Embase under “economic status”, whereas Cochrane used the phrase “socioeconomic factors”. The descriptions of each subject heading were consulted to ensure that cross-database meanings were the same. Although this method is lengthy, it produces a more comprehensive search strategy than using free-text terms in isolation (Lefebvre *et al.*, 2023). However, a value judgement between accuracy and sensitivity is required if this approach is taken. The inclusion of subject headings has the potential to retrieve significantly more irrelevant results than free-text terms alone because all references indexed under a given heading are returned (Lefebvre *et al.*, 2023).

A search string developed by the British Medical Journal (BMJ) Knowledge Centre to retrieve systematic reviews was utilised for Medline and adapted to each database (BMJ, 2022). BMJ Knowledge Centre search string was developed using the work of the InterTASC Information Specialists’ Sub-Group (ISSG) in collaboration with The Search Filters Resource and endured much testing to ensure an adequate balance between sensitivity and accuracy. The string can be viewed in Appendix 2.3.

To test the precision of the search strategy, pilot searches were performed to ascertain whether seven indicator papers were amongst the results. These articles were the same as those used to develop the strategy, (Arat *et al.*, 2019; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Fisher *et al.*, 2013; Gallagher *et al.*, 2016; Tabacchi *et al.*, 2016; Forshaw *et al.*, 2017; Bocquier *et al.*, 2017). The pilot searches outlined below were conducted using Medline (Ovid) in February 2022. For a more detailed overview of the results, please refer to Appendix 2.4.

Pilot Search 1 consisted of the **[Study design] AND [Exposure] AND [Outcome 1]** elements of the search strategy and returned 2087 results, including all seven key papers.

Pilot Search 2 consisted of the **[Study design] AND [Exposure] AND [Outcome 1] AND [Outcome 2]** elements of the search strategy and returned 1090 results, including all seven key papers.

Both pilot searches 1 and 2 returned the indicators papers, but the number of results was significantly reduced in the latter. Subsequently, the “Pilot Search 2” strategy was used.

2.3.5. Data sources and screening

The strategy was adapted to each of the following databases, which were searched in September 2022 (host sites given in parentheses): Medline (Ovid), Embase (Ovid), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (EBSCO), Cochrane CENTRAL, Science Citation Index (Web of Science), Database of Abstract Reviews of Effects, SCOPUS (Elsevier), and Applied Social Sciences Index and Abstracts (ASSIA) (ProQuest). Grey literature searching was conducted using the WHO repositories and PROSPERO.

After performing the searches, the records were downloaded and duplicated in Rayyan, an artificial intelligence tool used to streamline the systematic review process (Rayyan Systems, 2022). I performed the title and abstract screening, and a 10% sample was checked by a secondary reviewer (KT) and assessed against the eligibility criteria. I also performed the full-text screening stage, and a 10% sample was checked by the secondary reviewer (KT). The double-checking process confirms the eligibility criteria are being consistently applied. A third reviewer (AT) was consulted if an agreement could not be achieved. The eligible systematic reviews underwent forward and backwards citation chaining using Web of Science, whereby the article references and citations are screened for relevancy. Full-text screening was performed immediately when appropriate titles and abstracts were identified.

2.3.6. Data extraction

To facilitate the data extraction process, a form was designed to retrieve the following information from each of the systematic reviews: bibliographical details (author, year of publication, title, DOI, abstract), study design (satisfaction of the DARE criteria, method of synthesis, number of included studies); search specificities (databases, date, restrictions); any information relating to PICOS (geographical location, population, vaccine/s, definition of uptake, measures of socioeconomic inequality); the main findings/conclusions relevant to the umbrella reviews’ research questions (E.g., uptake

percentages (rates), counts, odds ratios); any potential mechanisms or pathways that may help account for the socioeconomic differences in vaccine uptake, as identified in the systematic review. The following information was also extracted from the primary studies if provided by the systematic review in which they were: authors, year of publication, vaccine/s of focus, geographical location, population, measures of socioeconomic inequality, risk of bias/quality verdict, overall uptake of the specified vaccine, and the main findings. I performed the data extraction and checked in full by the secondary reviewer (KT) for accuracy. Any disagreements were discussed with reviewer three (AT) to establish a consensus.

2.3.7. Dealing with overlap

In umbrella reviews, there is a risk of overlap whereby the same primary study is analysed in two or more systematic reviews (Pollock *et al.*, 2022). To understand the extent of the overlap, the Corrected Coverage Area (CCA) was calculated and reported (Pieper *et al.*, 2014). This approach is more sophisticated than simply calculating the overlap because it is not skewed by one primary study. For example, in a situation of ten included systematic reviews, each with 15 primary studies (150 primary studies in total), but only 140 are unique. This equates to 7% overlap. However, one primary study could be included in ten different reviews or five primary studies, each included in two reviews. In the former instance, one primary review would assert much more influence on the results than in the latter. A citation matrix was produced to calculate the CCA, where each unique primary study is represented by a row, and each column is a systematic review. Where these cells intersect, a “1” indicates the specified primary study is present, and a “0” indicates it is not. The formula to calculate CCA is as follows (Pieper *et al.*, 2014):

$$CCA = \frac{N - r}{(r \times c) - r}$$

N = total number of included publications, including double counting.

r = number of unique primary studies.

c = number of systematic reviews.

CCA interpretation:

- 0-5 = Slight overlap
- 6-10 = Moderate overlap
- 11-15 = High overlap
- >15 = Very high overlap

There are several methods of addressing overlap, but the chosen method must be informed by its extent. One solution is to completely or partially exclude reviews (Hennessy and Johnson). These decisions were discussed with the secondary reviewer (KT). However, as this umbrella review did not perform a meta-synthesis, overlap is not a critical issue. Nevertheless, it can be problematic for narrative syntheses if multiple populations, interventions, and outcomes are analysed because the prevalence of a sub-group finding could be inflated (Hennessy and Johnson).

2.3.8. Quality appraisal

A MeaSurement Tool to Assess Systematic Reviews (AMSTAR-2) was used to assess the methodological quality of the included systematic reviews. This tool was selected because it can be used to assess both randomised control trials and non-randomised studies of interventions (Shea *et al.*, 2017, pp.3-5). The checklist is presented in Table 2.2 comprises 16 questions, of which seven are considered “critical domains”, indicated by an asterisk (*).

Table 2.2 A MeaSurement Tool to Assess Systematic Reviews (AMSTAR-2) checklist criteria.

	Questions	Critical domain (*)
1	Did the research questions and inclusion criteria for the review include the components of PICO?	
2	Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	*
3	Did the review authors explain their selection of the study designs for inclusion in the review?	
4	Did the review authors use a comprehensive literature search strategy?	*
5	Did the review authors perform study selection in duplicate?	
6	Did the review authors perform data extraction in duplicate?	

7	Did the review authors provide a list of excluded studies and justify the exclusions?	*
8	Did the review authors describe the included studies in adequate detail?	
9	Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?	*
10	Did the review authors report on the sources of funding for the studies included in the review?	
11	If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results? *	
12	If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	
13	Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?	*
14	Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	
15	If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	*
16	Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	

It is not intended for AMSTAR-2 to produce an overall score but to identify areas of critical methodological weakness. The responses to each of the 16 questions were inputted into the online AMSTAR-2 tool that produces either a “high”, “moderate”, “low”, or “critically low” verdict (Shea *et al.*, 2017). The interpretations of these verdicts are as follows:

- **High** = no or one non-critical weakness.
- **Moderate** = more than one non-critical weakness.
- **Low** = one critical flaw with or without non-critical weaknesses.
- **Critically low** = more than one critical flaw with or without non-critical weaknesses.

The AMSTAR-2 result does not reflect the methodological quality of the primary studies analysed in the systematic reviews.

2.4. Methods: Narrative Synthesis

2.4.1. Research Question 1

Considering systematic reviews analysing both quantitative and qualitative primary studies were eligible for inclusion, a narrative synthesis was most appropriate. The narrative synthesis was guided by the Synthesis Without Meta-analysis recommendations, which uses a 9-item checklist (Mhairi *et al.*, 2020) and can be viewed in Appendix 2.5. To address Research Question 1 (Are there socioeconomic inequalities in vaccine uptake?), the synthesis consisted of three stages. Firstly, the following information was organised in a table and narratively synthesised: author(s), year of publication, vaccine(s) under study, the definition of uptake, geographical location, population specifics, total number of primary studies, number of relevant primary studies, and the measures of socioeconomic position. Each row in the table represented a unique systematic review.

Secondly, the results were summarised narratively according to the World Bank classifications – high-income countries (HIC) and low/middle-income countries (LMIC) (The World Bank, 2023), and the classification of findings. These classifications refer to whether the review exhibited evidence of inequalities, inverse, or mixed associations between socioeconomic position and vaccination uptake. They also identify whether these associations were consistent or inconsistent across the included primary studies. These are explained in more detail in Table 2.3. This approach to synthesis was appropriate, considering one of the limitations of the existing literature (discussed in Section 2.2.1, *Mapping relevant systematic reviews*). Namely, the lack of clarity regarding the direction of association between vaccination uptake and socioeconomic position. However, the use of the World Bank classifications has been criticised for not adequately representing between-country differences (Raphael and Sujaya, 2022). As a global umbrella review, however, a broad means of segmenting the findings was required.

To conclude the synthesis of findings related to Research Question 1, the findings of the reviews that employed meta-analyses are reported according to the analysed measure of socioeconomic position.

Table 2.3

A table explaining how the findings of the included systematic reviews were classified and the definitions of these classifications.

Classification of Findings	Definition
Inequalities (conventional)	1. Advantaged socioeconomic position, higher vaccination uptake AND/OR 2. Disadvantaged socioeconomic position, lower vaccination uptake. These associations are “conventional” because they reflect the conclusions of wider healthcare equity literature, as outlined in the introduction (Glymour, Avendano and Kawachi, 2015; Graham, 2007).
Inverse (unconventional)	1. Disadvantaged socioeconomic position, higher vaccination uptake AND/OR 2. Advantaged socioeconomic position, lower vaccination uptake. These associations are “unconventional” because they are not reflective of wider social inequalities nor the healthcare equity literature (Graham, 2007; Glymour, Avendano and Kawachi, 2015).
Mixed	Evidence of inequalities and inverse associations.
Consistent	There is evidence for the stated association (inequalities, inverse, or mixed) across all primary studies in the included systematic reviews.
Inconsistent	There is evidence for the stated association (inequalities, inverse, or mixed), but this is not found across all primary studies in the included systematic reviews.

2.4.2. Research Question 2

To address Research Question 2 (What are the mechanisms identified to explain such socioeconomic inequalities in vaccine uptake?), the extracted mechanisms were collated in a simple table before being mapped onto a patient-centred access to vaccination framework developed for this umbrella review. The first iteration of the framework was based on Levesque *et al.*'s (2013) patient-centred access to healthcare framework, which can be viewed in Appendix 2.6. Levesque *et al.*'s conceptualisation was selected because it is simplistic and could be easily adapted to vaccination. These adaptations were informed by the literature review in Chapter 1 and Section 2.2, *Literature Review*.

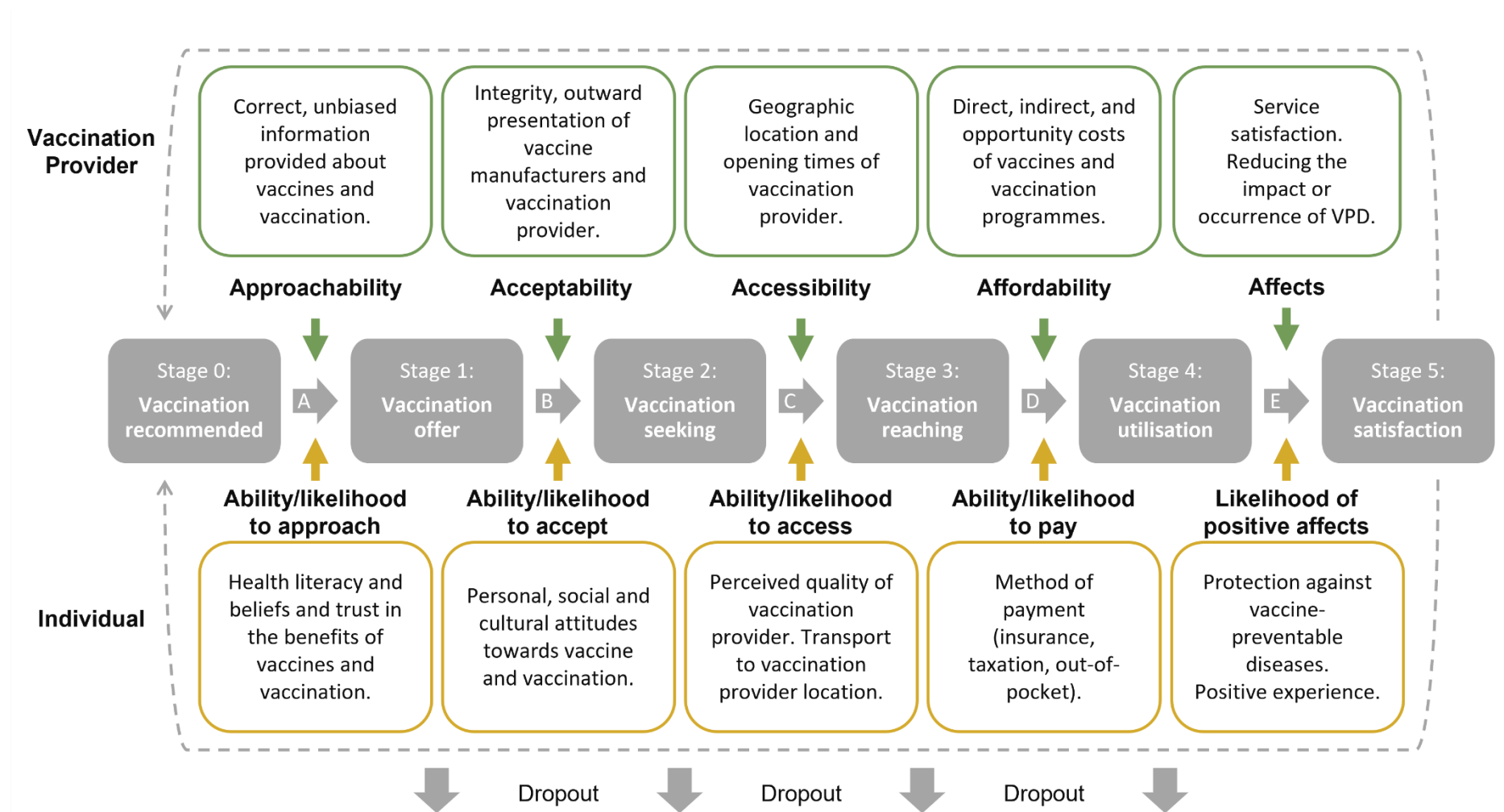
The framework (version 1) is depicted in Figure 2.1. The focal point of the diagram is the process of access to vaccination, depicted as stages 0 to 5: “Vaccination recommended”, “Vaccination offer”, “Vaccination seeking”, “Vaccination reaching”, “Vaccination utilisation”, and “Vaccination satisfaction”.

- The terms “approachability”, “acceptability”, “accessibility”, “affordability”, and “affects” refer to the considerations of the vaccination provider.
- The terms ability/likelihood to “approach”, “accept”, “access”, “pay”, and the likelihood of “positive affects” describe the concerns of the individual. Each of these terms can represent a barrier that prevents progress to the next stage.

This format closely mirrors Levesque *et al.*’s (2013) conceptualisation. Significant deviations from this would be unfounded without empirical research to support the changes. Nevertheless, the framework needed to demonstrate the vaccination process does not end with vaccination uptake; the overall experience could affect an individual’s likelihood of reengaging with the service. Reengagement is crucial to multi-dose vaccination schedules. Feedback loops and dropout arrows are included to depict this.

Mapping the mechanisms to the patient-centred access to vaccination framework would provide an understanding of the trickle-down effects of socioeconomic inequalities on vaccine uptake and ascertain which key stages of the vaccination process are impacted. A matrix-style table version was created to facilitate the mapping (see Appendix 2.7). Additionally, the umbrella review findings could assess the framework’s accuracy and determine whether further adaptations are required to improve this.

Figure 2.1 A framework depicting the access to vaccination and the considerations of the individual and vaccination provider at each stage (version 1). Adapted from Levesque *et al.*'s (2013) patient-centred access to healthcare framework.



2.5. Findings: Overview of Included Studies

2.5.1. Search results

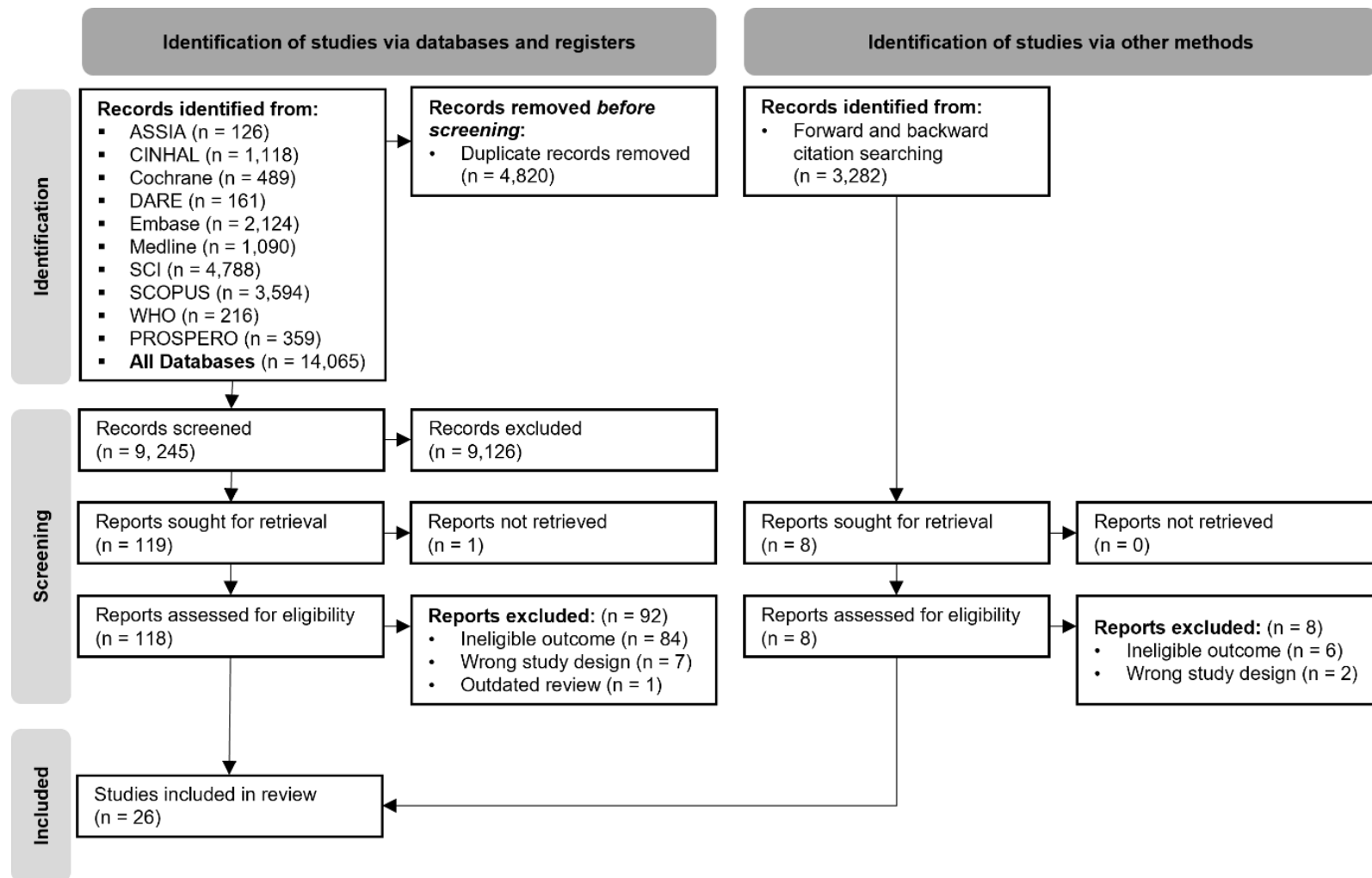
In total, 14,065 references were retrieved across the eight databases, and 9,163 after deduplication. Following title and abstract screening, the full texts of 119 articles were assessed for eligibility against the inclusion criteria, resulting in 26 included systematic reviews. The screening process is depicted in a PRISMA flow chart in Figure 2.2. Exclusion reasons for each of the 119 articles read at the full-text stage are presented in Appendix 2.8. Forward and backward citation chaining identified an additional 3,282 results. However, after the title and abstract screening and full-text eligibility assessment, no further systematic reviews met the criteria. No reviews published in a language other than English were eligible for inclusion.

2.5.2. Overlap assessment

The 26 systematic reviews analysed 689 primary studies. Of these, 94 were included in two or more reviews (13.64%), equating to 595 *unique* primary studies. The CCA was 0.6%, indicating a slight overlap according to Pieper *et al.*'s criteria (2014) – refer to Section 2.3.7, *Dealing with overlap*. Subsequently, no further action was taken. This decision was supported by the secondary reviewer (KT).

Figure 2.2

A completed PRISMA-flow diagram depicting the searching and screening process of the umbrella review.



2.5.3. Quality appraisal

Of the 26 reviews, all were deemed “critically low” methodological quality by AMSTAR-2. The responses to each of the 16 domains are presented in Table 2.4. Some key areas in which the included reviews frequently scored poorly were as follows (“critical domains” are indicated by an asterisk (*)):

Question 2* - not containing an explicit statement that the review methods were established prior to conducting the review (such as a protocol, or a study registration database) (n = 22).

Question 7* - not including a full list of excluded primary studies and their reasoning (n = 26).

Question 10 - not providing the funding details of each primary study (n = 24).

Question 13* - not accounting for risk of bias in the interpretation/discussion of results (n = 21).

Systematic reviews are a form of observational research, meaning it is important to establish the methods *a priori* to reduce bias by risking cherry-picking findings (Shea *et al.*, 2017) – only four of the included reviews provided this evidence. Secondly, by not providing a full list of excluded primary studies, a systematic review lacks transparency (Shea *et al.*, 2017). The potential impact and validity of not including these studies cannot be assessed if this information is not provided. However, the relevance of each AMSTAR-2 domain is dependent on the umbrella review (Shea *et al.*, 2017). For instance, failing to provide the funding details of the included primary studies could be a crucial oversight in the context of vaccination, as detailed in Section 1.3.4, *The MMR crisis 1998*. The majority of systematic reviews provide details of their funding; in some cases, it is unclear whether there may be conflicts of interest within their primary studies.

Table 2.4

Results of the quality appraisal for all 26 included systematic reviews using A MeaSurement Tool to Assess systematic Reviews (AMSTAR-2).

AMSTAR-2 Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Ali	Y	Y	Y	/	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	*
Arat	Y	N	Y	/	Y	N	N	Y	N	N			Y	Y		Y	*
Bocquier	Y	N	Y	/	Y	N	N	Y	Y	N			Y	Y		Y	*
De Casadevente	Y	N	Y	/	N	N	N	Y	N	N			N	Y		Y	*
Desalew	Y	Y	Y	/	Y	Y	N	/	Y	N	Y	Y	N	Y	y	Y	*
Do	Y	N	Y	/	N	N	N	Y	Y	N			N	Y		Y	*
Dyda	Y	N	Y	/	N	Y	N	Y	N	N	Y	N	N	Y	N	Y	*
Eshete	Y	N	Y	/	Y	Y	N	N	N	N	Y	N	N	Y	y	Y	*
Fisher	Y	N	Y	/	Y	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	*
Forshaw	Y	Y	Y	/	Y	N	N	Y	Y	N	Y	N	N	Y	y	Y	*
Galadima	Y	N	Y	/	Y	Y	N	/	Y	N			N	N		Y	*
Galbraith	Y	N	Y	/	N	N	N	/	N	N			N	N		Y	*
Gallagher	Y	N	Y	/	Y	Y	N	/	Y	N			N	Y		Y	*
Kessels	Y	N	Y	/	N	Y	N	/	Y	N			Y	Y		N	*
Loke	Y	N	Y	/	N	Y	N	/	Y	N			N	Y		Y	*
Lucyk	Y	N	Y	/	Y	Y	N	/	Y	N			N	Y		Y	*
Mansfield	Y	N	Y	/	Y	N	N	/	Y	N			Y	Y		Y	*
Murfin	Y	N	Y	/	N	N	N	Y	Y	N			Y	Y		Y	*
Nagata	Y	N	Y	/	Y	Y	N	/	N	N			N	Y		Y	*
Okoli	Y	Y	Y	/	Y	Y	N	/	Y	Y	Y	N	N	Y	Y	Y	*
Schellenberg	Y	N	Y	/	Y	N	N	/	N	N			N	Y		Y	*
Shenton	Y	N	Y	/	Y	Y	N	Y	N	N			N	Y		Y	*
Shin	Y	N	Y	/	Y	Y	N	/	Y	Y			N	Y		Y	*
Tauil	Y	N	Y	/	N	N	N	Y	N	N			N	Y		Y	*
Tilahun	Y	N	Y	/	N	Y	N	N	N	N			N	N		Y	*
Wang	Y	N	Y	/	N	Y	N	Y	Y	N	Y	N	N	Y	Y	Y	*
Yes	26	4	26	0	16	16	0	12	15	2	8	3	5	23	5	25	
Partial yes		0		26			0	12	0								
No	0	22	0	0	10	10	26	2	11	24	0	5	21	3	3	1	
No meta-analysis											18	18			18		

Key: Yes = Y, No = N, Partial yes = /

*Critically low overall verdict

2.5.4. Characteristics of included studies

The characteristics of the included systematic reviews are summarised in Table 2.5. Of the 26 included reviews, 18 narratively synthesised their findings (Fisher *et al.*, 2013; Forshaw *et al.*, 2017; Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020;

Okoli *et al.*, 2020; Wang *et al.*, 2018; Dyda *et al.*, 2016), and seven conducted a meta-analysis (Fisher *et al.*, 2013; Forshaw *et al.*, 2017; Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020; Okoli *et al.*, 2020; Wang *et al.*, 2018; Dyda *et al.*, 2016). One review (2016) conducted a meta-analysis, but the findings in relation to socioeconomic position were synthesised narratively. The remaining study (2022) performed both a substantial narrative synthesis and meta-analysis.

Several countries and geographical groupings were included: high-income countries (n = 14) (Arat *et al.*, 2019; Fisher *et al.*, 2013; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Gallagher *et al.*, 2016; Bocquier *et al.*, 2017; Dyda *et al.*, 2016; Do *et al.*, 2021; Galbraith *et al.*, 2016; Kessels *et al.*, 2012; Lucyk *et al.*, 2019; Mansfield, 2021; Murfin *et al.*, 2020; Shin *et al.*, 2022; Schellenberg and Crizzle, 2020), low/middle-income countries (n = 7) (Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020; Wang *et al.*, 2018; Shenton *et al.*, 2020; Ali *et al.*, 2022; Tilahun *et al.*, 2020; Galadima *et al.*, 2021), and a combination of high/low/middle-income countries (n = 5) (Forshaw *et al.*, 2017; Okoli *et al.*, 2020; Loke *et al.*, 2017; Nagata *et al.*, 2013; Taui, Sato and Waldman, 2016).

The analysed vaccines were as follows: childhood/adolescent vaccinations (n = 11) (Gallagher *et al.*, 2016; Arat *et al.*, 2019; Bocquier *et al.*, 2017; Schellenberg and Crizzle, 2020; Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020; Galadima *et al.*, 2021; Tilahun *et al.*, 2020; Shenton *et al.*, 2020; Forshaw *et al.*, 2017; Taui, Sato and Waldman, 2016), HPV (n = 10) (Fisher *et al.*, 2013; Mansfield, 2021; Do *et al.*, 2021; Galbraith *et al.*, 2016; Kessels *et al.*, 2012; Murfin *et al.*, 2020; Shin *et al.*, 2022; Loke *et al.*, 2017; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015), influenza (n = 4) and pneumococcal (n = 1) (Dyda *et al.*, 2016; Lucyk *et al.*, 2019; Wang *et al.*, 2018; Okoli *et al.*, 2020; Nagata *et al.*, 2013), and all routine vaccinations (n = 1) (Ali *et al.*, 2022).

Uptake was referred to, and measured, in various ways. Eight reviews did not define how they measured uptake (Arat *et al.*, 2019; Dyda *et al.*, 2016; Okoli *et al.*, 2020; Wang *et al.*, 2018; Galadima *et al.*, 2021; Lucyk *et al.*, 2019; Nagata *et al.*, 2013; Ali *et al.*, 2022), although five of these explored influenza vaccination which often has no specific schedule (Dyda *et al.*, 2016; Okoli *et al.*, 2020; Wang *et al.*, 2018; Lucyk *et al.*, 2019;

Nagata *et al.*, 2013). One review reported vaccine initiation (Shin *et al.*, 2022), and two reported schedule completion (Bocquier *et al.*, 2017; Shenton *et al.*, 2020). The remaining 15 reviews measured both vaccine initiation and completion (Bocquier *et al.*, 2017; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Desalew *et al.*, 2020; Do *et al.*, 2021; Eshete, Shewasinad and Hailemeskel, 2020; Fisher *et al.*, 2013; Forshaw *et al.*, 2017; Galbraith *et al.*, 2016; Gallagher *et al.*, 2016; Kessels *et al.*, 2012; Loke *et al.*, 2017; Mansfield, 2021; Murfin *et al.*, 2020; Schellenberg and Crizzle, 2020; Taail, Sato and Waldman, 2016).

The populations across the reviews varied due to the differing vaccines and their respective target groups. Amongst the publications that focused on childhood vaccines, three were of children under two years of age (Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020; Taail, Sato and Waldman, 2016), three under five years (Arat *et al.*, 2019; Galadima *et al.*, 2021; Shenton *et al.*, 2020), one under seven years (Schellenberg and Crizzle, 2020), two under twelve years (Bocquier *et al.*, 2017; Forshaw *et al.*, 2017), and one unspecified (Ali *et al.*, 2022). Of the reviews that examined HPV vaccination, five focused on females (de Casadevante and Gil Cuesta, 2015; Fisher *et al.*, 2013; Galbraith *et al.*, 2016; Kessels *et al.*, 2012; Murfin *et al.*, 2020; Shin *et al.*, 2022), one on males (Tilahun *et al.*, 2020), and three on both females and males (Do *et al.*, 2021; Loke *et al.*, 2017; Mansfield, 2021). Moreover, for the reviews that examined influenza vaccination, two explored adults aged 65 years and under (Nagata *et al.*, 2013; Okoli *et al.*, 2020), while three reviews had no population restrictions (Dyda *et al.*, 2016; Lucyk *et al.*, 2019; Wang *et al.*, 2018).

The findings relating to socioeconomic position were reported in one of two ways: according to individual measures (E.g., occupation, education, income, or deprivation/poverty) or under a subheading of “socioeconomic status” that incorporates two or more measures: five reviews used one measure ($n = 1$, area-level deprivation (Do *et al.*, 2021), $n = 4$, education (Eshete, Shewasinad and Hailemeskel, 2020; Forshaw *et al.*, 2017; Loke *et al.*, 2017; Wang *et al.*, 2018)), and the remaining 21 reviews utilised two, three, or four measures (E.g., socioeconomic status, education, income, wealth, area-level deprivation, occupation, or employment). These measures were operationalised in

vastly different ways. It was common for reviews focusing on children or adolescents to refer only to maternal education rather than a combined parental measure. In the reviews that employed a meta-analysis, it was easier to ascertain the operationalisation of socioeconomic position than those that did not.

Table 2.5

A table detailing the characteristics of all 26 systematic reviews analysed in this umbrella review.

Author (year) Funding	Relevant studies (total) Search Date	Vaccine/s Uptake	Location	Population	Measures of socioeconomic position
Ali (2022) <i>Narrative synthesis Meta-analysis</i> Funding: Gavi, the Vaccine Alliance, and by the Bill Melinda Gates Foundation	Relevant studies: 87 narratively synthesised, 22 of which were included in the meta-analysis (108) Search date: June 15 th 2021 (end of publication restriction)	BCG ^a , OPV/IPV ^b , MCV ^c , DTP ^d (EPI^e 1974) EPI + Hep B ^f ; EPI + Hep B, MMR; EPI + Hep B, JE ^g ; EPI + Hep B, Hib ^h ; EPI + Hep B, Hib, YF ⁱ ; EPI + Hep B, Hib, MMR; DTP, MCV, BCG; DTP; MCV; IPV/OPV; Hep; Influenza; Other; Not given Uptake: Unspecified ¹	Low and middle-income countries: Afghanistan, Bangladesh, Brazil, Cambodia, Cameroon, China, Eswatini, Ethiopia, Gambia, Ghana, India, Indonesia, Kenya, Kyrgyz Republic, Laos, Madagascar, Malawi, Mongolia Mozambique, Myanmar, Namibia, Nepal, Nigeria, Pakistan, South Africa, Tanzania, Thailand, Togo, Uganda, Various (unspecified), Vietnam, Zambia	General Eligible children, adolescents and adults	Wealth Occupation Maternal education
Arat (2019) <i>Narrative synthesis</i> Funding: European Commission	Relevant studies: 15 (15 articles, 14 studies) Search date: July 20 th 2017	DTP MMR Uptake: Undefined ²	EEA/EFTA countries and Australia: Australia, Belgium, France, Germany, Greece, Ireland, Italy, Netherlands, Spain, Sweden, UK	General Children under 5 years	Parental income Education Occupation Area-level SES

Bocquier (2017) Narrative synthesis Funding: Agence Nationale de Sécurité du Médicament et des Produits de Santé (ANSM) and the Agence Nationale de la Recherche (ANR).	Relevant studies: 34 (43 articles, 41 studies) Search date: April 12 th 2016 (end of publication restriction)	Series: DTP, Polio, Hib; DTP, Polio, Hib, MMR; DTP, Polio, Hib, Varicella; DTP, Polio, Hib, PCV ⁱ , MenC; PCV; Men C; Varicella; Influenza; Rotavirus; Hep B; Hep A; Polio; Pertussis; Hib Uptake: Individual vaccine uptake Series completion	Developed countries: US, Canada, Belgium, UK, Ireland, Germany, Greece, Italy, Australia	General Children under 12 years	Parental income Education Occupation Combination of the above
De Casadevante (2015) <i>Narrative synthesis</i> Funding: Not provided.	Relevant studies: 16 (23) Search date: April 2014 (end of publication restriction)	HPV ^l Uptake: Initiation (1/2 doses) Completion (3 doses)	Europe: Netherlands, Sweden, Denmark, Belgium, Italy, France, Germany, UK, Scotland, Greece	General Eligible females, no age restriction	Education Deprivation Employment Parental income
Desalew (2020) <i>Meta-analysis</i> Funding: No financial support declared.	Relevant studies: 28 (38) Search date: 2020 (end of publication restriction)	Series (EPI 1974): DTP, Polio, Measles, BCG EPI 2004: Hep B, Hib, PCV, Rotavirus Uptake: Initiation	Ethiopia	General Children aged 12-23 months	Maternal education Maternal occupation Wealth status Husband employment

		Completion			
Do (2021) <i>Narrative synthesis</i> Funding: National Cancer Institute	Relevant studies: 11 (25) Search date: February 2019, updated February 2020	HPV Uptake: Initiation Completion = 3 doses Missed opportunities ^k	USA	General Adolescent (unspecified age) males and females.	Area-level poverty
Dyda (2016) <i>Narrative synthesis</i> <i>Meta-analysis</i> Funding: PhD scholarship National Health and Medical Research Council	Relevant studies: 2 (22) Search date: May 31 st 2015 (end of publication restriction)	Influenza Pneumococcal Uptake: Unspecified	Australia	General Adults ≥65 and <65	Education Income Meta-analysis conducted, but SE inequalities reported in narrative format.
Eshete (2020) <i>Meta-analysis</i> Funding: No financial support declared.	Relevant studies: 30 (30) Search date: April 2019 – August 2019, updated January 20 th 2020	Series (EPI 974): DTP, Polio, Measles, BCG Epi 2004: Hep B, Hib, PCV, Rotavirus Uptake: Incompletion Completion x1 BCG, x3 Penta (DTP, Hep B, Hib), x3 Polio, x3 PCV, x2 Rotavirus, x1 Measles	Ethiopia	General Children 12-23 months	Maternal education

Fisher (2013) <i>Meta-analysis</i> Funding: Centre for the Development and Evaluation of Complex Interventions for Public Health Improvement (DECIPHer)	Relevant studies: 19 (29 articles, 27 studies) Search date: March 9 th 2012 (end of publication restriction)	HPV Uptake: Initiation Completion	Not specified: USA, Belgium, Netherlands, Canada, UK	Females ≤ 18 years	Income/area level deprivation Education
Forshaw (2017) <i>Meta-analysis</i> Funding: PhD scholarship National Institute for Health Research	Relevant studies: 37 (37) Search date: June 29 th 2016	Series (EPI 974): DTP, Polio, Measles, BCG EPI (2004): Hep B, Hib, PCV, Rotavirus Uptake: Initiation Completion	Global: Iraq, Ethiopia, Nigeria, Uganda, Brazil, USA, Kenya, India, Greece, Bangladesh, Malawi, Mali, Belgium, Zimbabwe, Burkina Faso, Zambia, Indonesia, Vietnam, Turkey, Cameroon	General Mothers with children under 12 years	Maternal education
Galadima (2021) <i>Narrative synthesis</i> Funding: No financial support declared.	Relevant studies: 15 (51) Search date: October 26 th 2020 (end of publication restriction)	Series (EPI): BCG, OPV, Hep B, DTP, Measles, YF Uptake: Unspecified, any	Africa: Angola, Burkina Faso, Cameroon, Congo, Ethiopia, Gambia, Ghana, Kenya, Mozambique, Nigeria Tanzania, Uganda	General Children under 5 years	Parental education Maternal occupation Income

Galbraith (2016) <i>Narrative synthesis</i> Funding: No financial support declared.	Relevant studies: 4 (67) Search date: January 2015 (end of publication restriction)	HPV Uptake: Initiation Completion	USA	African Americans and/or Latinos Female caregivers of females aged 10-19 years	Poverty Income Education
Gallagher (2016) <i>Narrative synthesis</i> Funding: Medical Research Council, UK, Instituto de Salud Carlos III, Agència de Gestió d'Ajuts Universitaris i de Recerca, and European Community's Seventh Framework Programme	Relevant studies: 14 (61) Search date: February 2014	Adolescent schedule if not given prior to aged 10: DTP; HPV; Men conjugate; Influenza; Hep A; Hep B; MMR; Tick borne encephalitis; JE; Typhoid; Cholera; Rabies; Varicella Uptake: Initiation Completion <i>Only DTP, HPV, and influenza were analysed.</i>	No restrictions: Canada, USA, France, Various (unspecified), Australia, UK, Greece, Peru	General Adolescents, aged 9-19 years	Median neighbourhood or parental income Average adult education Poverty status Maternal education
Kessels (2012) <i>Narrative synthesis</i> Funding: Australian Research Council Linkage	Relevant studies: 11 (33 articles, 25 studies) Search date:	HPV Uptake: Initiation Completion	No restrictions: USA, Canada, Australia, UK, Netherlands, France	General Adolescents, eligible females aged 9-18 years	Parental education Family income

Grant Project	March 7 th 2011 (end of publication restriction)				
Loke (2017) <i>Narrative synthesis</i> Funding: No financial support declared.	Relevant studies: 7 (42) Search date: March 4 th 2017 (end of publication restriction)	HPV Uptake: First dose (initiation) Third dose (completion)	Unspecified: USA, UK, Norway, The Netherlands, Germany, France, Denmark, Latvia, Hong Kong, Taiwan, Malaysia, Japan, Canada, Australia	General Adolescents, males, and females	Maternal education
Lucyk (2019) <i>Narrative synthesis</i> Funding: University of Calgary and the Alberta Ministry of Health	Relevant studies: 22 (42) Search date: May 2017 (end of publication restriction)	Influenza (Seasonal and pandemic) Uptake: Undefined	High-income countries: USA, Canada, Denmark, Belgium, South Korea, Japan, Germany, Australia, Israel, New Zealand, UK, Italy, Ireland, Poland, Spain	General No restrictions	Education Occupational class Income/poverty
Mansfield (2021) <i>Narrative synthesis</i> Funding: National Institute of Nursing Research of the National Institutes of Health	Relevant studies: 5 (57) Search date: January 2020	HPV Uptake: Initiation Completion	USA	General Parents of, or adolescents, aged 9-18, males and females	Socioeconomic status Poverty status
Murfin (2018) <i>Narrative synthesis</i> Funding: Not provided.	Relevant studies: 6 (10) Search date: June 13 th 2018	HPV Uptake: Initiation Completion	Developed countries: Norway, USA, Germany	General Eligible females	Education Income Occupation

Nagata (2011) <i>Narrative synthesis</i> Funding: Initiative for Vaccine Research and the Social Determinants of Health Unit at the World Health Organization	Relevant studies: 10 (58) Search date: January 2011	Influenza Uptake: Undefined	Unspecified: Asia, Europe, Latin America, Middle-East, various (unspecified)	General Adults < 65	Education Socioeconomic status Deprivation
Okoli (2020) <i>Narrative synthesis</i> Funding: GlaxoSmithKline, Merck, Sanofi Pasteur, Pfizer and Roche-Assurex	Relevant studies: 20 (34) Search date: January 2018, updated January 7 th 2020	Influenza Uptake: Undefined	Not specified: Spain, USA, UK, Europe, China, Israel, Italy, Ireland, France, Australia, Thailand, Canada, South Korea, Switzerland, Singapore, Serbia, Japan	General Adults ≥65 years	Household income Education Social class Employment
Schellenberg (2020) <i>Narrative synthesis</i> Funding: Not provided.	Relevant studies: 8 (12) Search date: October 2019 (end of publication restriction)	Vaccination status: MMR; Varicella; DTP; Hib; Meningococcal; PCV; Rotavirus; Hep B Uptake: Initiation Completion	Canada	General Children, aged ≤ 7 years	Household income Parental education Unemployment rate
Shenton (2020) <i>Narrative synthesis</i> <i>Scoping review</i> Funding:	Relevant studies: 83% (125) Percentages of relevant studies were provided,	Routine vaccination, EPI schedule 1974: BCG; DTP; Polio; Measles 2004:	Demographic and Health Survey countries: Malawi, India, Kazakhstan, Nepal, Vietnam, Nigeria, Bangladesh, Philippines,	General Children, aged > 60 months	Maternal education Wealth index Paternal education

National Institute of Allergy And Infectious Diseases of the National Institutes of Health	instead of exact numbers. Search date: December 31 st 2018 (end of publication restriction)	Hep B; Hib; Rubella; PCV; Rotavirus Uptake: Completion	Indonesia, Burkina Faso, Cambodia, Tanzania, Kenya, Nepal, Uganda, Burundi, Pakistan, Madagascar, Ethiopia, Bolivia, Ghana, Zimbabwe, Benin, Senegal, DRC, Afghanistan, Various (unspecified)		
Shin (2022) <i>Narrative synthesis</i> Funding: Ministry of Education	Relevant studies: 14 (30) Search dates: July 2020 (end of publication restriction)	HPV Uptake: Initiation	No restrictions: USA, Denmark	General Eligible boys/men	Parental educational level Parental employment status Household income
Tauil (2016) <i>Narrative synthesis</i> Funding: PhD scholarship Coordination for the Improvement of Higher Education Personnel (CAPES)/São Paulo Research Foundation	Relevant studies: 10 (23) Search dates: July 17 th 2014 – July 21 st 2014	Routine vaccination: DTP (x3); Polio (x3); Measles (x1) Uptake: Incompletion Completion	Global: Burkina Faso, Mozambique, Kenya, Philippines, Brazil, Belgium, Canada, USA	General Caregivers of children, aged ≤ 24 months	Maternal education Socioeconomic status Mother working inside/outside the home

Tilahun (2020) <i>Scoping Review</i> Funding: Alliance for Health Policy and Systems Research	Relevant studies: 15 (55) Search dates: November 28 th 2018	Routine vaccination (EPI programme of Ethiopia): DTP, Polio, Measles, BCG Uptake: Completion	Ethiopia (National and regional)	General Children, aged ≤ one year	Household economic status Caregiver and/or mother's education Caregiver and/or mother's occupation
Wang (2018) Meta-analysis Funding: Chinese National Natural Fund, Science Technology Demonstration Project for Emerging Infectious Diseases Control and Prevention, Jiangsu Provincial Six Talent Peak, Jiangsu Provincial Key Medical Discipline	Relevant studies: 25 (126) Cannot specifically identify which relevant studies are included. Search dates: March 18 th 2018	Influenza Uptake: Undefined	Mainland China	General Not specified	Education

1 Unspecified – no restrictions were placed on the measure of uptake.

2 Undefined – there was no mention of eligible measures of uptake.

a BCG - Bacillus Calmette-Guérin vaccine, protecting against Tuberculosis.

b OPV/IPV – Oral Poliovirus vaccine/inactivated poliovirus vaccine.

c MCV – Measles-containing vaccine.

d DTP – Diphtheria-Tetanus-Pertussis vaccine.

e EPI – Expanded Programme on Immunisation.

f Hep B – Hepatitis B vaccine.

g JE – Japanese Encephalitis vaccine.

h Hib – Haemophilus Influenzae type B vaccine.

i YF – Yellow Fever vaccine.

j PCV – Pneumococcal vaccine.

k Missed opportunities – A clinical encounter when at least one adolescent vaccination was received, where another vaccine could have been administered as well.

2.6. Findings: Research Question 1

2.6.1. Socioeconomic inequalities in routine vaccination uptake

In summary, all 26 reviews reported an association between socioeconomic position and vaccination uptake. However, the nature of these associations was complex. The results are presented in Table 2.6. The findings were summarised using the following classifications, as outlined in Section 2.4.1, *Research Question 1*:

Inequalities (conventional)

1. Advantaged socioeconomic position, higher vaccination uptake, AND/OR
2. Disadvantaged socioeconomic position, lower vaccination uptake

Inverse (unconventional)

1. Disadvantaged socioeconomic position, higher vaccination uptake, AND/OR
2. Advantaged socioeconomic position, lower vaccination uptake.

Mixed – Evidence of inequalities and inverse associations.

Consistent – There is evidence for the stated association (inequalities, inverse, or mixed) across all primary studies in the included systematic reviews.

Inconsistent – There is evidence for the stated association (inequalities, inverse, or mixed), but this is not found across all primary studies in the included systematic reviews.

Evidence for inequalities was identified in 24 reviews. However, in over half of these (n = 15), the overall conclusions were that of mixed findings, as support for inverse associations was also identified. In the remaining two reviews, only inverse associations were identified. Thus, 17 reviews in total found evidence for inverse associations: lower vaccination uptake for advantaged socioeconomic groups (n = 6) (Census 2021, 2023; Ali *et al.*, 2022; Arat *et al.*, 2019; Bocquier *et al.*, 2017; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Loke *et al.*, 2017; Taui, Sato and Waldman, 2016), higher uptake for disadvantaged socioeconomic groups (n = 7) (Do *et al.*, 2021; Dyda *et al.*, 2016; Galbraith *et al.*, 2016; Kessels *et al.*, 2012; Lucyk *et al.*, 2019; Nagata *et al.*, 2013;

Schellenberg and Crizzle, 2020), or both (n = 4) (Census 2021, 2023; Mansfield, 2021; Murfin *et al.*, 2020; Shenton *et al.*, 2020; Shin *et al.*, 2022).

Overall, the differing measures of socioeconomic position did not appear to explain the varying conclusions. Income, education, occupation/employment, and area-level deprivation were neither more nor less frequently associated with vaccination uptake. Similarly, mixed findings were equally prevalent across all measures. This result is also evident for different vaccinations. Additionally, there was no evidence to suggest that a particular vaccine, or group of vaccines, were more or less prone to socioeconomic differences in uptake; mixed results were equally common for all vaccines.

Table 2.6

Summary of systematic review findings by vaccine and association with socioeconomic group.

	Inequalities	Inverse	Mixed
	Advantaged socioeconomic position, higher vaccination uptake, AND/OR disadvantaged socioeconomic position, lower vaccination uptake.	Disadvantaged socioeconomic position, higher vaccination uptake, AND/OR advantaged socioeconomic position, lower vaccination uptake.	Evidence of inequalities and inverse associations.
Human Papillomavirus vaccine	Fisher (2013) (MA) (n = 19) ¹	Mansfield (2021) (Na) (n = 5) ²	de Casadevante (2015) (Na) (n = 16) ¹ Do (2021) (Na) (n = 11) ² Galbraith (2016) (Na) (n = 4) ¹ Kessels (2012) (Na) (n = 11) ¹ Murfin (2020) (Na) (n = 6) ¹ Shin (2022) (Na) (n = 14) ¹ Loke (2017) (Na) (n = 7) ²
Influenza vaccine	Wang (2018) (MA) (n = 25) ² Okoli (2020) (MA) (n = 20) ¹	Dyda (2016) (Na) (n = 2) ²	Nagata (2013) (Na) (n = 10) ¹ Lucyk (2019) (Na) (n = 22) ¹
All routine vaccinations			Ali (2022) (MA/Na) (n = 87) ¹
Childhood and/or adolescent routine vaccinations	Gallagher (2016) (Na) (n = 14) ¹ Desalew (2020) (MA) (n = 28) ¹ Eshete (2020) (MA) (n = 30) ² Galadima (2021) (Na) (n = 15) ² Tilahun (2020) (Na) (n = 15) ¹ Forshaw (2017) (MA) (n = 37) ¹		Arat (2019) (Na) (n = 15) ¹ Bocquier (2017) (Na) (n = 34) ¹ Schellenberg (2020) (Na) (n = 8) ¹ Shenton (2020) (Na) (n = 125*) ¹ Tauil (2016) (Na) (n = 10) ²
Key			

Low uptake identified for both advantaged and disadvantaged socioeconomic groups.	Low uptake identified for disadvantaged socioeconomic groups.	Low uptake identified for advantaged socioeconomic groups.
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¹Inconsistent associations (there is evidence for the stated association (inequalities, inverse, or mixed), but this is not found across all primary studies in the included systematic review).

²Consistent associations (there is evidence for the stated association (inequalities, inverse, or mixed) across all primary studies in the included systematic review).

MA = Meta-analysis, Na = Narrative synthesis

*125 primary studies were included in the scoping review, but only a percentage of relevant studies were provided, not an exact number.

A summary of the systematic review findings by country economic status and association with socioeconomic group is presented in Table 2.7. The association between socioeconomic position and vaccination uptake was more complex among higher-income than low/middle-income countries, as evidence for mixed and inverse associations was more prevalent.

2.6.2. Low/middle-income countries

Seven reviews focused on low/middle-income countries (Ali *et al.*, 2022; Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020; Galadima *et al.*, 2021; Shenton *et al.*, 2020; Tilahun *et al.*, 2020; Wang *et al.*, 2018). Of these seven, five explored the childhood/adolescent vaccination schedule (Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020; Galadima *et al.*, 2021; Shenton *et al.*, 2020; Tilahun *et al.*, 2020); two found evidence for consistent inequalities (Eshete, Shewasinad and Hailemeskel, 2020; Galadima *et al.*, 2021), another two inconsistent inequalities (Desalew *et al.*, 2020; Tilahun *et al.*, 2020), and one had mixed findings (Shenton *et al.*, 2020). In a review analysing influenza vaccination, there was evidence to support a conclusion of consistent inequalities (Wang *et al.*, 2018). The seventh review analysed uptake of all routine vaccinations (childhood/adolescent and adulthood) and conducted both a substantial narrative synthesis and meta-analysis (Ali *et al.*, 2022). In this review, the narrative synthesis showed consistent, mixed results, whereas the meta-analysis demonstrated consistent evidence of inequalities. Overall, in the context of LMIC, the findings largely suggest there are socioeconomic inequalities in vaccination uptake.

2.6.3. High-income countries

Most reviews (n = 14) focused exclusively on high-income countries (Gallagher *et al.*, 2016; Fisher *et al.*, 2013; Dyda *et al.*, 2016; Mansfield, 2021; Arat *et al.*, 2019; Bocquier *et al.*, 2017; Do *et al.*, 2021; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Galbraith *et al.*, 2016; Kessels *et al.*, 2012; Murfin *et al.*, 2020; Shin *et al.*, 2022; Lucyk *et al.*, 2019; Schellenberg and Crizzle, 2020). Four of these analysed the childhood/adolescent vaccination schedule, with mixed and inconsistent associations with socioeconomic position in three reviews (Arat *et al.*, 2019; Bocquier *et al.*, 2017;

Schellenberg and Crizzle, 2020), and inconsistent evidence of inequalities in one (Gallagher *et al.*, 2016). A further eight reviews explored HPV vaccination (de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Do *et al.*, 2021; Fisher *et al.*, 2013; Galbraith *et al.*, 2016; Kessels *et al.*, 2012; Mansfield, 2021; Murfin *et al.*, 2020; Shin *et al.*, 2022); one found consistent evidence of inverse associations with socioeconomic position (Mansfield, 2021), one inconsistent inequality (Fisher *et al.*, 2013), and one consistent mixed (Do *et al.*, 2021). The remaining five reviews that explored HPV vaccination were inconsistent and mixed (de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Galbraith *et al.*, 2016; Kessels *et al.*, 2012; Murfin *et al.*, 2020; Shin *et al.*, 2022). One review analysing influenza and pneumococcal vaccination uptake identified some consistent support for inverse associations with socioeconomic position (Dyda *et al.*, 2016). Another review exploring influenza vaccination found inconsistent and mixed results (Lucyk *et al.*, 2019). Broadly, these results suggest that vaccination uptake varies within HIC and across socioeconomic groups, but the results are often mixed and inconsistent. This conclusion applies to all vaccines.

2.6.4. High/middle/low-income countries

Five reviews explored a combination of high, middle, and low-income countries (Forshaw *et al.*, 2017; Loke *et al.*, 2017; Nagata *et al.*, 2013; Okoli *et al.*, 2020; Tauil, Sato and Waldman, 2016). Two of which focused on the childhood/adolescent schedule (Forshaw *et al.*, 2017; Tauil, Sato and Waldman, 2016); one identified inconsistent support for socioeconomic inequalities in uptake (Forshaw *et al.*, 2017), whereas the other found consistently mixed associations (Tauil, Sato and Waldman, 2016). Another review exhibited consistent and mixed results for socioeconomic position and HPV vaccination (Loke *et al.*, 2017). Okoli *et al.* (2020) and Nagata *et al.* (2013) analysed the uptake of influenza vaccination; the former identified inconsistent support for socioeconomic inequalities, whereas the latter showed inconsistent evidence for mixed associations. Overall, reviews conducted in the context of high/middle/low-income countries identified mixed and inconsistent findings in vaccination uptake across different socioeconomic groups across all vaccines analysed.

Table 2.7

Summary of systematic review findings by country economic status and association with socioeconomic group.

	Inequalities	Inverse	Mixed
	Advantaged socioeconomic position, higher vaccination uptake, AND/OR disadvantaged socioeconomic position, lower vaccination uptake.	Disadvantaged socioeconomic position, higher vaccination uptake (↓), AND/OR advantaged socioeconomic position, lower vaccination uptake (↑), or both (↕).	Evidence of inequalities and inverse associations.
High-income countries	Gallagher (2016) (Na) (n = 14) ¹	Dyda (2016) (Na) (n = 2) ² ↓	Arat (2019) (Na) (n = 15) ¹ ↑
	Fisher (2013) (MA) (n = 19) ¹	Mansfield (2021) (Na) (n = 5) ² ↕	Bocquier (2017) (Na) (n = 34) ¹ ↑
			de Casadevante (2015) (Na) (n = 16) ¹ ↑
			Do (2021) (Na) (n = 11) ² ↓
			Galbraith (2016) (Na) (n = 4) ¹ ↓
			Kessels (2012) (Na) (n = 11) ¹ ↓
			Lucyk (2019) (Na) (n = 22) ¹ ↓
			Murfin (2020) (Na) (n = 6) ¹ ↕
Low, middle-income countries	Desalew (2020) (MA) (n = 28) ¹		Schellenberg (2020) (Na) (n = 8) ¹ ↓
	Eshete (2020) (MA) (n = 30) ²		Shin (2022) (Na) (n = 14) ¹ ↕
	Galadima (2021) (Na) (n = 15) ²		Ali (2022) (MA/Na) (n = 87) ¹ ↑
	Tilahun (2020) (Na) (n = 15) ¹		Shenton (2020) (Na) (n = 125*) ¹ ↕
	Wang (2018) (MA) (n = 25) ²		
High, middle, low-income countries	Forshaw (2017) (MA) (n = 37) ¹		Loke (2017) (Na) (n = 7) ² ↑
	Okoli (2020) (MA) (n = 20) ¹		Nagata (2013) (Na) (n = 10) ¹ ↓
			Tauil (2016) (Na) (n = 10) ² ↑

Key:

Human Papillomavirus vaccination (HPV).	Influenza and/or Pneumococcal vaccination.	All routine vaccinations (childhood and adult).	Childhood/adolescent vaccination schedule.
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¹Inconsistent associations (there is evidence for the stated association (inequalities, inverse, or mixed), but this is not found across all primary studies in the included systematic review).

²Consistent associations (there is evidence for the stated association (inequalities, inverse, or mixed) across all primary studies in the included systematic review).

MA = Meta-analysis, Na = Narrative synthesis

*125 primary studies were included in the scoping review, but only a percentage of relevant studies were provided, not an exact number.

2.6.5. Meta-analysed reviews

All six reviews that employed a meta-analysis found evidence of inequalities, albeit inconsistently (Desalew *et al.*, 2020; Eshete, Shewasinad and Hailemeskel, 2020; Forshaw *et al.*, 2017; Okoli *et al.*, 2020; Wang *et al.*, 2018). However, Fisher *et al.* (2013) performed a meta-analysis of HPV vaccination initiation, but not for completion, where they identified evidence of inequalities. On the other hand, the reviews that narratively synthesised their findings (n = 19) or performed both a substantial narrative synthesis and meta-analysis (n = 1) found evidence for inequalities, inverse associations, and mixed findings. Thus, reviews that narratively synthesised identified a broader range of outcomes than those that performed a meta-analysis.

In three reviews that meta-analysed their findings, maternal education was significantly associated with a 129% (odds ratio (OR) 2.29, 95% confidence interval (CI) 1.19 to 2.75) (Eshete, Shewasinad and Hailemeskel, 2020), 96% (OR 1.96, 95% CI 1.40 to 2.74) (Desalew *et al.*, 2020), and 165% (2.65 OR, 95% CI 12.08 to 3.37) (Forshaw *et al.*, 2017) greater odds of full childhood immunisation than lower levels of maternal education. However, Fisher *et al.* (2013) identified no association with lower maternal education in their meta-analysis of HPV vaccine initiation. A further two reviews found higher levels of education are associated with a 12% (OR 1.12, 95% CI 1.04 to 1.21) (Okoli *et al.*, 2020), and 30% (OR 1.3, 95% CI 1.1 to 1.6) (Wang *et al.*, 2018) increase in the odds of influenza vaccination compared to those with lower levels of education. Two of these reviews disaggregated their findings by continent; in Asia, the odds of full childhood immunisation were increased by 165% if the mother was educated when compared to uneducated mothers (OR 2.65, 95% CI 2.08 to 3.37) (Forshaw *et al.*, 2017). However, another review found a non-significant association between education and influenza vaccination for the same continent (Okoli *et al.*, 2020). For Africa, this was a 134% increase (OR 2.34, 95% CI 1.69 to 3.24) (Forshaw *et al.*, 2017), and a 22% increase in North America (OR 1.22, 95% CI 1.02 to 1.47) (Okoli *et al.*, 2020). Where one review found a 47% increase in the odds of childhood vaccination uptake in Europe (OR 1.47, 95% CI 1.14 to 1.89) (Forshaw *et al.*, 2017), the other did not find a significant association (Okoli *et al.*, 2020).

Employed fathers were 51% less likely to not fully immunise their child compared to unemployed fathers (OR 0.49, 95% CI 0.35 to 0.67) (Desalew *et al.*, 2020); maternal occupation was non-significant.

In one review, lower household income was associated with an 11% decrease in influenza vaccination overall (OR 0.9, 95% CI 0.85 to 0.95), with a 9% decrease in Asia (OR 0.91, 95% CI 0.84 to 0.99) and 15% in North America (OR 0.85, 95% CI 0.76 to 0.96) (Okoli *et al.*, 2020). However, income was not associated with HPV vaccination initiation (Fisher *et al.*, 2013), or full childhood immunisation (Desalew *et al.*, 2020) in a further two reviews.

One review identified a non-significant association between residing in areas of higher deprivation and HPV vaccine uptake (Fisher *et al.*, 2013).

A high social class was associated with a 20% increase in influenza vaccination (OR 1.20, 95% CI 1.06 to 1.36) in one review (Okoli *et al.*, 2020).

2.7. Findings: Research Question 2

2.7.1. Extracted mechanisms

Most of the included reviews (n = 16) described potential mechanisms that could explain the association between vaccination uptake and socioeconomic position. The following mechanisms were hypothesised and had not been tested by the review authors: vaccine cost (n = 2) (Bocquier *et al.*, 2017; Mansfield, 2021); access to transport (n = 3) (Bocquier *et al.*, 2017; Desalew *et al.*, 2020; Galadima *et al.*, 2021); time costs (n = 1) (Bocquier *et al.*, 2017); the extent of maternal control over household resources (n = 1) (Galadima *et al.*, 2021); lack of confidence (in vaccination in general, or in oneself to make decisions about uptake) (n = 6) (Bocquier *et al.*, 2017; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Desalew *et al.*, 2020; Galadima *et al.*, 2021; Nagata *et al.*, 2013; Schellenberg and Crizzle, 2020); commitment to health-seeking behaviour (n = 3) (Bocquier *et al.*, 2017; Galadima *et al.*, 2021; Loke *et al.*, 2017); vaccination knowledge (access to relevant information and/or ability to understand this information) (n = 7) (Bocquier *et al.*, 2017; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Desalew *et al.*, 2020; Galadima *et al.*, 2021; Nagata *et al.*, 2013; Schellenberg and Crizzle,

2020; Wang *et al.*, 2018); attitudes or beliefs about vaccination (n = 3) (Galadima *et al.*, 2021; Mansfield, 2021; Schellenberg and Crizzle, 2020); trust in healthcare or vaccination providers (n = 3) (Loke *et al.*, 2017; Nagata *et al.*, 2013; Schellenberg and Crizzle, 2020); ease of access (based on the type of healthcare system) (n = 3) (Ali *et al.*, 2022; Forshaw *et al.*, 2017; Okoli *et al.*, 2020); the vaccine delivery strategy (facility versus school-based) (n = 2) (Galadima *et al.*, 2021; Murfin *et al.*, 2020); funding of the vaccination programme (n = 2) (Lucyk *et al.*, 2019; Taul, Sato and Waldman, 2016). The identified mechanisms were mapped onto the patient-centred access to vaccination framework presented in Section 2.4.2, *Research Question 2*. The results of this are presented in Table 2.8.

The identified mechanisms classified as provider considerations were related to accessibility and affordability. The individual considerations were concerned with “ability and/or likelihood to approach”, “ability and/or likelihood to accept”, “ability and/or likelihood to access”, and “ability and/or likelihood to pay”.

Table 2.8

Extracted mechanisms explaining the link between socioeconomic status and vaccination uptake, as identified by the included reviews, mapped onto the patient-centred access to vaccination framework (Sacre *et al.*, 2022).

	Mediators	Explanation	Mechanism	Reference
A ↓	Approachability (provider)	“Correct, unbiased information provided about vaccines and vaccination.”		
	Ability and/or likelihood to approach (individual)	“Health literacy and beliefs and trust in the benefits of vaccines and vaccination.”	Commitment to health-seeking behaviour	(Bocquier <i>et al.</i> , 2017; Galadima <i>et al.</i> , 2021; Loke <i>et al.</i> , 2017)
			Vaccination knowledge (access to relevant information and/or ability to understand information)	(Bocquier <i>et al.</i> , 2017; Desalew <i>et al.</i> , 2020; Wang <i>et al.</i> , 2018; Galadima <i>et al.</i> , 2021; Nagata <i>et al.</i> , 2013; Schellenberg and Crizzle, 2020; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015)
B ↓	Acceptability (provider)	“Integrity, outward presentation of vaccine manufacturers and vaccination provider.”		
	Ability and/or likelihood to accept (individual)	“Personal, social, and cultural attitudes towards vaccine and vaccination.”	Lack of confidence (in vaccination in general, or in oneself to make decisions about uptake)	(Bocquier <i>et al.</i> , 2017; Desalew <i>et al.</i> , 2020; Loke <i>et al.</i> , 2017; Mansfield, 2021; Nagata <i>et al.</i> , 2013; Schellenberg and Crizzle, 2020)
			Extent of maternal control over household resources	(Galadima <i>et al.</i> , 2021)
			Attitudes/beliefs about vaccination	(Galadima <i>et al.</i> , 2021; Mansfield, 2021; Schellenberg and Crizzle, 2020)
C ↓	Accessibility (provider)		Vaccine delivery strategy (facility versus school-based)	(Gallagher <i>et al.</i> , 2016; Murfin <i>et al.</i> , 2020)

		“Geographic location and opening times of vaccination provider.”	Ease of access (based on the type of healthcare system)	(Forshaw <i>et al.</i> , 2017; Okoli <i>et al.</i> , 2020; Ali <i>et al.</i> , 2022)
	Ability and/or likelihood to access (individual)	“Perceived quality of vaccination provider. Transport to vaccination provider location.”	Access to transport	(Bocquier <i>et al.</i> , 2017; Desalew <i>et al.</i> , 2020; Galadima <i>et al.</i> , 2021)
			Trust in healthcare or vaccination provider	(Loke <i>et al.</i> , 2017; Nagata <i>et al.</i> , 2013; Schellenberg and Crizzle, 2020)
D ↓	Affordability (provider)	“Direct, indirect, and opportunity costs of vaccines and vaccination programmes.”	Funding of vaccination programme	(Lucyk <i>et al.</i> , 2019; Tauil, Sato and Waldman, 2016)
	Ability and/or likelihood to pay (individual)	“Method of payment (insurance, taxation, out-of-pocket).”	Vaccine cost	(Bocquier <i>et al.</i> , 2017; Mansfield, 2021)
			Time costs	(Bocquier <i>et al.</i> , 2017)
E	Affects (provider)	“Service satisfaction. Reducing the impact or occurrence of VPD.”		
	Likelihood of positive affects (individual)	“Protection against vaccine-preventable diseases. Positive experience.”		
(provider) = considerations of vaccination providers, (individual) = considerations of the vaccination decision maker.				

2.8. Discussion

2.8.1. Summary

This review aimed to (1) examine whether there are socioeconomic inequalities in vaccination uptake and summarise the contexts in which they exist and (2) identify any mechanisms that could potentially explain these inequalities. The review demonstrated evidence of socioeconomic inequalities in vaccination uptake, but the literature on this topic is complex. There are several key findings: Firstly, in LMIC, there appears to be consistent evidence for inequalities, such as lower vaccine uptake amongst disadvantaged socioeconomic groups or higher vaccine uptake amongst advantaged socioeconomic groups. Secondly, the picture was more variable for reviews analysing HIC with evidence for inequalities and inverse associations (either low uptake for advantaged or high uptake for disadvantaged socioeconomic groups). Thirdly, most reviews provided mechanisms that may explain the association between socioeconomic position and vaccination uptake. The two most frequently cited mechanisms were reduced vaccination knowledge (access to relevant information and/or ability to understand this information) and a lack of confidence (in vaccination in general or in oneself to make decisions about uptake). Finally, reviews that narratively synthesised their findings included a broader range of outcomes than those that conducted a meta-analysis, identifying more evidence of inequalities.

Moreover, the AMSTAR-2 checklist rated all 26 systematic reviews as “critically low” methodological quality. The implications of this for this umbrella review are discussed in Section 2.8.4, *Limitations*. Other umbrella reviews which used this tool found similar results; all included reviews were rated as either low or critically low (Chen *et al.*, 2022; Li *et al.*, 2022). Given that both randomised control trials and randomised studies of interventions were analysed, AMSTAR-2 was the most appropriate quality appraisal tool for this review, but that does not reconcile its evident bluntness (Shea *et al.*, 2017).

2.8.2. Understanding the findings

It is important to appreciate the context to understand the first finding of the umbrella review (consistent evidence for socioeconomic inequalities in vaccination uptake in

LMIC). According to UNICEF (2022), of the 25 million children who were under-vaccinated in 2021, more than 60% reside in 10 LMIC countries – India, Nigeria, Indonesia, Ethiopia, Philippines, the Democratic Republic of the Congo, Brazil, Pakistan, Angola, and Myanmar. Inequalities may be more apparent in settings with lower overall uptake than in areas with higher overall uptake because there is a lower baseline; thus, the contrast is starker. Another explanation for consistent evidence of socioeconomic inequalities in uptake for LMIC could be related to the role of education in these contexts. In their meta-analysis, Forshaw *et al.* (2017) found that the positive effect of increasing maternal education on complete childhood vaccination was lower in Europe than in Asia or Africa. Subsequently, Forshaw *et al.* suggested maternal education may be more important in LMIC than in HIC. However, this does not mean education is unimportant in HIC.

Higher levels of education can also be associated with lower uptake in high-income countries. This is intertwined with the third finding of the umbrella review, related to the extracted mechanisms. In their systematic review exploring attitudes towards HPV vaccination in the United States, Mansfield *et al.* (2021, p. 485) suggested that “*Parents' educational attainment and vaccine beliefs may explain lower vaccination rates among high-income families*”. Namely, as the level of education increases, there may be a greater commitment to health-seeking behaviour, which can either have a positive or negative effect on uptake, a fact identified by other included reviews (Bocquier *et al.*, 2017; Galadima *et al.*, 2021; Loke *et al.*, 2017). Although many review authors suggest this is the case, it perpetuates an elitist perspective that those with lower levels of education are less committed to health-seeking behaviour. This narrative is unhelpful for those experiencing socioeconomic disadvantage.

Nevertheless, the role of education appears to act as both a potential barrier and promoter of vaccination uptake. This is linked to the second finding of the umbrella review (the associations between vaccination uptake and socioeconomic position were more variable in HIC than in LMIC). Thus, the previous suggestion that the level of education is more important in LMIC than HIC is inaccurate when considering that lower levels of uptake are evident amongst more advantaged socioeconomic groups in these high-income settings. A more accurate statement would be that the level of education is equally important across country-economic settings, but the manifestation is different.

Concerning higher uptake amongst disadvantaged socioeconomic groups in HIC, Mansfield *et al.* (2021) suggested that this may be the result of eligibility for government-funded healthcare assistance. This claim is supported by the fact that influenza vaccination is government-funded in Australia, where a disadvantaged income and education were associated with greater uptake odds than more advantaged groups (Dyda *et al.*, 2016). Several factors may, therefore, contribute to the association between socioeconomic position and vaccination uptake. The country context should be considered to understand how these associations manifest.

The two most frequently cited mechanisms were vaccination knowledge (access to relevant information and/or ability to understand this information) and lack of confidence (in vaccination in general or in oneself to make decisions about uptake). Schellenberg *et al.*'s review (2020, p. 581) exhibited mixed findings and suggested a “*complex interplay may exist among education, vaccine concerns, and trust*”. Knowledge and confidence are both referenced in the wider literature as impacting uptake; for instance, in a systematic review investigating parental views of the HPV vaccine, Marshall *et al.* (2019) identified five themes: (1) is prevention better than cure, (2) the fear of the unknown, (3) limited knowledge and understanding, (4) complex vaccination decisions, and (5) parental responsibility. Thus, this is not a new finding, but highly citable works like systematic reviews must refer to mechanisms carefully. These statements may perpetuate unhelpful discourses that are not grounded in empirical research.

This review established that socioeconomic position could impact several stages of the vaccination process, as presented in Table 2.8. The patient-centred access to vaccination framework proved a useful tool in organising the extracted mechanisms. However, it became apparent that the framework may not adequately portray cross-entity considerations. For instance, “vaccine delivery strategy (facility versus school-based)” (Gallagher *et al.*, 2016; Murfin *et al.*, 2020) and “Ease of access based on the healthcare system” (Nagata *et al.*, 2013; Okoli *et al.*, 2020; Forshaw *et al.*, 2017) are often decided by powers greater than the vaccination provider and thus represent a policy issue. Another shortfall of the framework is that it does not accurately capture the importance of access to vaccination information and subsequent knowledge

development. This suggests that the framework may require alterations to account for this, which is further discussed in Chapter 3.

This umbrella review was unable to ascertain the overall impact of different measures of socioeconomic position due to a lack of clarity in most included systematic reviews. It was often unclear which outcomes related to which measures. To avoid making inaccurate, broad, sweeping statements – a common issue in umbrella reviews (Pollock *et al.*, 2022) – this avenue of synthesis was not pursued in all reviews. However, this was easier to ascertain in meta-analysed reviews. These results demonstrated that similar outcomes were identified for all measures of socioeconomic position, specifically support for socioeconomic inequalities in vaccination uptake. This is not an unexpected finding, as measures of socioeconomic position are intertwined (Evans, Wolfe and Adler, 2012). However, the more interesting outcome of this sub-synthesis was the comparison between narratively synthesised and meta-analysed reviews; a wider range of outcomes (evidence for inverse and mixed associations) were exhibited in narratively synthesised reviews. The inclusion criteria for meta-synthesised reviews could be more specific to reduce heterogeneity and prevent analysis. Additionally, most of the meta-analysed systematic reviews focused on LMIC countries. Less variability in the outcome of these studies could link to increasing complexity in the association between socioeconomic position and vaccination uptake in HIC.

2.8.3. Implications of the findings

This umbrella review has synthesised a large body of literature. It concisely describes the association between vaccination uptake and socioeconomic position globally. The existing literature does acknowledge this heterogeneity (Larson *et al.*, 2014), but fails to portray the extent of the complexity adequately. This is important to consider when designing interventions to increase uptake. Investigating why more advantaged socioeconomic groups are at risk of lower uptake would be helpful when striving to achieve herd immunity vaccination uptake targets. Interventions must target *all* individuals with low uptake, which may include advantaged as well as disadvantaged socioeconomic groups. This umbrella review has highlighted the need for commissioners

and providers of vaccination programmes to understand the association between socioeconomic position and vaccination uptake intimately within their population.

Despite many of the included reviews exploring multiple measures of socioeconomic position, any discussions surrounding potential mechanisms were often understood by authors as being linked via education. Whilst this is an interesting interpretation, the included systematic reviews often failed to explain the link between other measures of socioeconomic position and vaccination uptake. This perpetuates a blame culture and neglects to acknowledge the structural barriers that are present. Subsequently, those working in policy and practice may orient their interventions to increase uptake towards education when, in fact, support needs to be directed elsewhere. This review highlights the need for more research into the legitimacy and accuracy of these claims.

2.8.4. Limitations

Although there were overlaps in primary studies, which had been synthesised in two or more systematic reviews, the CCA (0.6%) demonstrated this was not a significant concern. No further action was taken after consulting with the secondary reviewer (KT).

The first limitation of the umbrella review was that it did not identify any systematic reviews exploring COVID-19 vaccination uptake that were eligible for inclusion. However, a scoping review conducted by Dalton *et al.* (Dalton *et al.*, 2023) explored the impact of COVID-19 on routine childhood immunisations in low/middle-income countries. They analysed 58 relevant studies, approximately one-quarter of which showed that routine childhood vaccination uptake declined during 2019-2021. The decline in uptake ranged from 10% to 38% in the studies that identified this association. However, 52 of the included primary studies explored a single country, meaning the evidence was not diverse. This is a drawback of systematic reviewing and establishing inclusion criteria *a priori*. Whilst the lack of COVID-19 reviews is a limitation of the umbrella review as a stand-alone study, it is not in the context of the thesis. It establishes the literary foundation of socioeconomic inequalities in vaccination uptake unrelated to the pandemic. Primary studies exploring this association are discussed in Chapter 3.

Secondly, there were two adaptations to the methodology since the publication of the protocol (Sacre *et al.*, 2022). Firstly, the study design inclusion criteria were broadened to allow for studies that analysed secondary data. Many identified systematic reviews synthesised primary studies that analysed secondary data from national or regional vaccination registries, as this is where the data is often held. Excluding reviews that did so would eliminate an important source of information and a common approach taken by review authors. The second adaptation was the reframing of the inclusion criteria using PECOS in replacement of PICOS (Population, intervention, comparator, outcome, and study design), as the former conceptualisation was more appropriate.

Thirdly, an umbrella review is the second level of abstraction; the first is the synthesis of primary studies into systematic reviews, and the second is systematic reviews into an umbrella review. Details are lost in this process, and there is a reliance on systematic review authors interpreting the results of the included primary studies accurately. If their interpretation is inaccurate, this can negatively impact the legitimacy of the umbrella review's synthesis. This issue is pertinent when considering all included systematic reviews were rated "critically low" by the AMSTAR-2 checklist. However, it is important to note that AMSTAR-2 is a blunt instrument, with reviews undergoing an automatic downgrade if they do not satisfy one of the "critical domains" (Shea *et al.*, 2017). Although randomised control trials are considered the gold standard for evidence-based medicine, the quality of systematic reviews is lacking (Li *et al.*, 2012).

2.8.5. Recommendations

Two academic recommendations stemmed from the umbrella review: Firstly, systematic review authors must be more explicit in detailing their PICO criteria. At a minimum, the vaccine should be stated, the number of doses (including the number required for full immunisation), and the target age of administration – this is especially relevant when comparing multiple countries as routine schedules are likely to vary.

Furthermore, it is important for authors conducting systematic reviews to carefully consider the assessment tools that could be used to appraise their work, such as AMSTAR-2. In doing so, they will have a greater awareness of the criteria that they should satisfy to be awarded a higher rating. However, it must be acknowledged that word counts

for journals are often limited, which could be a contributing factor when reviews do not offer enough detail.

On the other hand, the AMSTAR-2 tool is a blunt instrument which could reflect the methodological quality nuances across reviews better. For instance, for question eight (“Did the review authors describe the included studies in adequate detail?”), five criteria need to be satisfied to receive a “yes” verdict: described populations in detail, described intervention in detail, described comparators in detail, described study’s setting, and timeframe for follow-up. If one element is not reported, the verdict will either be “partial yes” or “no”. Instead, the response to this AMSTAR-2 question could be represented as a percentage with an overall verdict to clarify where included reviews are lacking specifically. This is one example of an adaption that would improve AMSTAR-2.

2.8.6. Suggestions for future research

Firstly, future research could further adapt the patient-centred access to vaccination framework, utilising the umbrella review findings to ground it in empirical research and improve its accuracy.

Secondly, the legitimacy of the mechanisms identified could be investigated. This could be performed through quantitative data analysis (if appropriate data are available) or qualitative methods. Professionals involved in vaccination programmes could be interviewed to ascertain their opinions on the role of education in vaccination uptake. Additionally, healthcare system professionals involved in monitoring or commissioning these programmes could provide insight into why vaccination uptake may not always conform to a socioeconomic gradient. As the type of vaccine determines many different routes to vaccination and mechanisms, it would be appropriate to analyse a subset. Focusing on a specific geographical location would allow for a more in-depth exploration.

Thirdly, research could be conducted into the association between socioeconomic deprivation, COVID-19 and vaccination uptake, as this was not addressed in this review. After doing so, the umbrella review findings can be used to compare the state of uptake from a pre- and post-COVID-19 perspective. This would provide a comprehensive overview of the topic.

2.8.7. Conclusion

This chapter aimed to address thesis Objective 1 by examining whether there are socioeconomic inequalities in vaccination uptake, summarising the contexts in which they exist and identifying any mechanisms that could potentially explain these inequalities. The review demonstrated evidence of socioeconomic inequalities in vaccination uptake, but the literature on this topic is complex. Nevertheless, these associations did not consistently follow a clear gradient. Review authors frequently mentioned education as the driving force behind socioeconomic differences in uptake and the link to the identified mechanisms. Professionals involved in vaccination programmes must know how these differences manifest in their population to design effective interventions to increase uptake.

Chapter 3 utilises the findings of this umbrella review to inform the second component of the thesis: a mixed methods study exploring socioeconomic inequalities in vaccination uptake in England. It provides an overview of the English vaccination programme before exploring the COVID-19 literature. It aims to justify the need for a mixed methods investigation and outlines the approach.

Chapter 3. **Socioeconomic Inequalities in Childhood Vaccination in England: Mixed Methods Methodology.**

3.1. Introduction

3.1.1. Chapter overview

Chapter 1 introduced the fundamental concepts of this thesis relating to health and healthcare inequalities and vaccination. Chapter 2 explored a subset of the discourse, socioeconomic inequalities in routine vaccination uptake, and how these narratives are framed in evidence synthesis. Chapter 3 further narrows the scope, enabling a deeper exploration using a mixed methods approach. The project was funded by the National Institute for Health and Care Research (NIHR) Applied Research Collaboration (ARC) North East and North Cumbria (NENC) and, therefore, seeks to produce findings relevant to policy and practice in England. Thus, this chapter first explains how the umbrella review findings will shape the rest of the thesis as applied to England. Next, the appropriateness and usefulness of narrowing the scope to childhood vaccinations are argued. Building on this information, a literature review is performed to identify relevant studies and where the research is currently lacking and, in so doing, justify the need for further study. Next, the issues of ontology and epistemology are addressed. The patient-centred access to vaccination framework is adapted, as informed by the umbrella review and the Socio-ecological Model of Health, before explaining how this will be utilised further in Chapter 6. Lastly, reflexivity is discussed, and the mixed methods model employed to integrate the quantitative and qualitative components is described. Chapter 3, therefore, aims to establish a solid literary foundation for the mixed methods study on which the empirical Chapters 4 (quantitative component) and 5 (qualitative component) are built.

3.1.2. Narrowing the scope

The umbrella review identified that the association between socioeconomic position and vaccination uptake in some high-income countries does not always adhere to a gradient. Nine systematic reviews included primary studies that explored England (Arat *et al.*,

2019; Bocquier *et al.*, 2017; de Casadevante, Gil Cuesta and Cantarero-Arévalo, 2015; Fisher *et al.*, 2013; Gallagher *et al.*, 2016; Kessels *et al.*, 2012; Loke *et al.*, 2017; Lucyk *et al.*, 2019): the human papillomavirus vaccine (HPV) (n = 4), the childhood/adolescent vaccination schedule (n = 4), and influenza/pneumococcal (n = 2). Inverse and mixed findings were equally prevalent across these reviews, although it is unclear whether they were identified in an English context from the umbrella review synthesis. Thus, any of these vaccines would warrant further exploration.

However, Bocquier *et al.*'s (2017) suggest that the Measles, Mumps, and Rubella (MMR) vaccine is susceptible to lower uptake for advantaged socioeconomic groups. The mixed methods study could investigate the legitimacy of this statement. Additionally, the decline in MMR vaccine uptake in England has been described as “alarming” by members of parliament (MPs), and the UK Health Security Agency (UKHSA) has warned outbreaks of Measles could occur if uptake rates do not improve (Limb, 2023). This statement was made in 2023, meaning that the uptake of Measles-containing vaccinations is a contemporary concern in England. Further research could investigate whether other vaccinations administered during childhood are affected. In England, childhood vaccinations are classified as those offered from 0-5 years old (as depicted in Table 3.1). As referenced in Section 1.3.4, *The 1998 MMR crisis*, Anderberg *et al.* (2011) claim there were “spillover” effects of lower uptake levels on other routine childhood vaccinations associated with the 1998 MMR crisis. The mixed methods study could explore if a similar effect has occurred regarding the COVID-19 vaccine. For example, in April 2021, under 40-year-olds were recommended to receive alternatives to the Astra Zeneca COVID-19 vaccine due to concerns with blood clots – a risk that decreases with age (England, 2021). In May 2021, this was extended to under 30-year-olds. Although not directly related to childhood vaccination, adults are the vaccination decision-makers for their children.

Subsequently, the second and third thesis objectives were altered to account for this refined scope:

Objective 2 – Quantitatively analyse whether there has been a change in socioeconomic inequalities in **childhood** vaccination uptake in England associated with the COVID-19 pandemic.

Objective 3 – Qualitatively explore the landscape of delivering, commissioning, supporting, and monitoring the **childhood** vaccination programme with a specific focus on areas of high socioeconomic deprivation.

Objective 4 – Connect the findings from the umbrella review, quantitative analysis, and qualitative study to provide a comprehensive overview of socioeconomic inequalities in vaccination uptake on a global, national, and regional level.

An overview of healthcare and the childhood vaccination programme in England is provided before exploring the empirical research on this topic.

3.2. Background

3.2.1. *The English healthcare system*

Healthcare in England recently experienced a significant transformation. Public Health England (PHE) devolved in 2021 into the United Kingdom Health Security Agency (UKSHA) and the Office for Health Improvement and Disparities (OHID). The Health and Care Act 2022 aimed to provide streamlined services for those with multiple needs by creating a collaborative network of various organisations known as Integrated Care Systems (ICSs), of which there are 42 in England (NHS England, 2024e). ICSs are comprised of three main elements: the Integrated Care Board (ICB), the Integrated Care Partnerships (ICP), and Upper-tier Local Authorities (UTLA). The ICB is responsible for handling the NHS budget for the ICS, which is also overseen by one of the seven NHS England regional teams. ICPs engage non-NHS stakeholders, such as local authorities, in planning and delivering care in their area. For example, the North East and Yorkshire regional commissioning team oversees four ICBs: Humber and North Yorkshire, North East and North Cumbria, South Yorkshire, and West Yorkshire.

The Department of Health and Social Care (DHSC) provide national strategic oversight of vaccination policy in England, with advice from the independent Joint Committee on Vaccination and Immunisation (JCVI) and the Commission on Human Medicines. The UK Health Security Agency undertake surveillance of vaccine-preventable diseases, such as prevalence and locations of outbreaks. However, NHS England is responsible for

commissioning the immunisation programme in England according to section 7a, the public health functions: immunisation programmes, population screening programmes, child health information services, public health services for children and adults in secure and detained settings, and sexual assault services (Department of Health & Social Care, 2023). There are regional teams for each public health function, which include a team lead and various managers who preside over a specific aspect, such as the childhood vaccination programme.

UTLAs do not commission the childhood programme; however, as part of the ICBs, their involvement is in a supportive capacity to improve the health of their population using the tools available to them, such as health promotion and the Health Visitor Service (Powell, 2023). The Health Visitor service is one component of the 0-19 Healthy Child Programme, focusing on children 0-5 years old. The school nursing service deals with children and adolescents 5-19 years old, including adolescent vaccinations (Office for Health Improvement & Disparities, 2023).

The childhood immunisation programme is funded through GP contracts, such as General Medical Service Contracts (GMS) and Personalised Medical Service Contracts (PMS), meaning childhood vaccines are ordinarily delivered in GP surgeries or child health clinics. NHS England uses the GP contract to outline their expectations and guidance on how to deliver the childhood vaccination programme (NHS England, 2024b). As individual businesses, GP practices can implement the programme differently, providing they meet NHS England requirements. Practice funding is determined using a Global Sum calculation. Firstly, the Contractor's Registered Population (CRP), or GP patient list, is multiplied by £107.57 (NHS England, 2024a) – the current patient cost. Then, the Carr-Hill formula adjusts this figure based on the needs of the registered patients. There are six indicators: patient age and sex, patient additional needs, list turnover, staff market forces factor, rurality, and number of residential and nursing home patients (Rhys, Beerstecher and Morgan, 2010). Indeed, this is a simplified overview of GP funding, but it provides the fundamentals.

Another source of income is the Quality Outcome Framework (QOF). There are several service-delivery targets that, if met, financially reward practices. These relate to the diagnosis, recording, and initial and ongoing management of various illnesses (NHS

England, 2024d). However, payments are rewarded for childhood vaccinations that achieve high coverage. The QOF targets for immunisation for children under five years for the 2024/25 financial year are as follows (NHS England, 2024d):

- Babies who reached eight months old in the preceding 12 months, who have received at least three doses of DTP-containing vaccine before eight months old (89-96% = 18 QOF points).
- Children who reached 18 months old in the preceding 12 months, who have received at least one dose of MMR between the ages of 12 and 18 months (86-96% = 18 QOF points).
- Children who reached five years old in the preceding 12 months, who have received a reinforcing dose of DTaP/IPV and a least two doses of MMR between the ages of one and five years (81-96% = 18 QOF points).

Thus, 54 QOF points are available for childhood vaccination. For this indicator, payments are calculated using two metrics: the number of QOF points achieved (one point is worth £220.62) and the Contractor Population Index (CPI) (practice list size divided by the national average list size, which is 9,964 for 2024/25) (Ardens, 2024). The formula is presented in Formula 3.1. Practices can earn substantial additional income from QOF if targets are achieved.

Formula 3.1

Quality outcome framework (QOF) formula.

$$QOF\ points * £220.62 * CPI$$

3.2.2. The English childhood vaccination schedule

The routine vaccination schedule has been developed to provide the UK public with the best possible protection from vaccine-preventable diseases (VPDs). In most cases, multiple doses of the same antigen are required to maximise the strength and longevity of protection. In alignment with the World Health Organisation's (WHO) recommendations, the coverage target for all routine childhood vaccinations is 95% (NHS Digital, 2023b). The schedule can be viewed in Table 3.1, alongside the ages they are administered, the antigens they protect against, and the required doses for full

protection. This is a recommended schedule as vaccination is not mandatory in the UK, thus, there are no legal repercussions if parents decide not to vaccinate their children.

Table 3.1

Routine childhood vaccinations offered by the NHS.

Age given	Vaccine	Antigen(s)	Dose(s)
8 weeks	6-in-1 vaccine (DTaP/IPV/Hib/HepB)	Diphtheria, Tetanus, Pertussis (DTaP), polio (IPV), Haemophilus influenzae type B (Hib), and Hepatitis B (HepB)	1 st of 3
	Rotavirus vaccine (Rota)	Rotavirus	1 st of 2
	MenB vaccine (MenB)	Meningitis B	1 st of 3
12 weeks	6-in-1 vaccine (DTaP/IPV/Hib/HepB)	Diphtheria, Tetanus, Pertussis (DTaP), polio (IPV), Haemophilus influenzae type B (Hib), and Hepatitis B (HepB)	2 nd of 3
	Pneumococcal vaccine (PCV)	Pneumococcus	1 st of 2
	Rotavirus vaccine (Rota)	Rotavirus	2 nd of 2
16 weeks	6-in-1 vaccine (DTaP/IPV/Hib/HepB)	Diphtheria, Tetanus, Pertussis (DTaP), polio (IPV), Haemophilus influenzae type B (Hib), and Hepatitis B (HepB)	3 rd of 3
	MenB vaccine (MenB)	Meningitis B	2 nd of 3
1 year	Hib/MenC vaccine (Hib/MenC)	Haemophilus influenzae type B (Hib), Meningitis C (MenC)	1 st of 1
	MMR vaccine (MMR)	Measles, mumps, and rubella	1 st of 2
	Pneumococcal vaccine (PCV)	Pneumococcus	2 nd of 2
	MenB (MenB)	Meningitis B	3 rd of 3
2 to 15 years	Flu vaccine	Influenza	Annually
3 years, 4 months	MMR vaccine (MMR)	Measles, mumps, and rubella	2 nd of 2
	4-in-1 pre-school booster vaccine	Diphtheria, Tetanus, Pertussis (DTaP), Polio (IPV)	1 st of 1
6 months to 17 years	Flu vaccine	Influenza Eligibility: babies and children with long-term health conditions.	Annually

Additional vaccines are available to “at-risk” babies, such as the Hepatitis B vaccine for those born to mothers with Hepatitis B and Tuberculosis (BCG) for babies (or their parents/grandparents) born in countries with high rates of the disease.

Overall, the uptake of childhood vaccinations in England is relatively high, and the occurrence of vaccine-preventable diseases is low. However, in August 2018, the WHO’s European Regional Verification Commission for Measles and Rubella Elimination (RVC) determined the UK had lost its measles elimination status. Since 2010, the most Measles cases occurred in 2012, with 2,052 confirmed occurrences (UK Health Security Agency, 2023). The elimination status was regained in 2021 when opportunities to spread the disease were limited due to the pandemic (UK Health Security Agency, 2023). As of 5th August 2024, there have been 2,278 confirmed measles cases since January of the same year (UK Health Security Agency, 2024). The success of the childhood vaccination programme is returned to in Chapter 4.

3.3. Literature Review

3.3.1. Search overview

The search strategy used for the umbrella review (presented in Section 2.3.4, *Search strategy and pilot searches*) was adapted to search for relevant literature relating to COVID-19, socioeconomic inequalities and childhood vaccination in the context of England. The study design terms were removed, and two additional “setting” groups were included, as follows:

[Setting 1]

AND

Title, Abstract, Key words=

COVID-19 or COVID 19 or COVID19 or corona* or pandemic

[Setting 2]

AND

Title, Abstract, Key words=

England or UK or United Kingdom or Great Britain or Britain

The searches were conducted in Medline and Web of Science, as well as forward and backwards citation chaining to identify relevant studies. Additionally, the systematic

reviews that were not eligible for inclusion in the umbrella review were sought, and their relevant primary studies. The key findings of the searches are explored below.

An abundance of qualitative research on parental attitudes towards childhood vaccination was identified. A critical review by Torracinta *et al.* (2021), published in 2021, explored attitudes and uptake of the MMR vaccine in the UK. Authors grouped their findings into five categories: (1) uptake and demographics, (2) beliefs and attitudes, (3) healthcare worker focus, (4) experimental and psychometric interventions, (5) mixed methods. Whilst the review itself did not provide enough information regarding socioeconomic inequalities, the included primary studies exploring uptake and demographics provided some insight. A disadvantaged socioeconomic position and/or those experiencing greater levels of deprivation significantly contribute to lower levels of MMR uptake (Sandford *et al.*, 2015; Haider, Willocks and Anderson, 2019; Hungerford *et al.*, 2016; Baker, Garrow and Shiels, 2011). A further three identified fears of MMR as the ultimate reason parents decided not to vaccinate (Gardner *et al.*, 2010; Brown *et al.*, 2012; Hill and Cox, 2013). Thus, there is existing evidence to support the notion that the MMR vaccine is susceptible to socioeconomic inequalities in uptake. Despite being published in 2021, Torracinta *et al.*'s review did not capture the additional impact of COVID-19. A systematic review conducted by Spencer *et al.* (2022), concluded that inequalities in childhood vaccination uptake did increase during the early stages of the pandemic in high-income countries. However, there wasn't much of a focus or discussion of England in this review.

3.3.2. Mixed methods research

Four mixed methods studies (Skirrow *et al.*, 2022; Skirrow *et al.*, 2021; Skirrow *et al.*, 2024; Bell *et al.*, 2021) and one multi-method study (Buck *et al.*, 2023), investigating the impact of COVID-19 and childhood vaccination were identified. Within these, authors used a combination of survey questionnaires or routinely collected uptake data for their quantitative component, and interviews or focus groups for the qualitative. Three of the four mixed methods studies were authored by Skirrow *et al.* (2022; 2021; 2024). One focused on the delivery of the childhood vaccination programme in London during the pandemic, where parents felt that booking and attending appointments were

increasingly difficult, coupled with a lack of appointment reminders (Skirrow *et al.*, 2021). Another of Skirrow *et al.*'s (2022) studies investigated women's views and experiences of accessing pregnancy pertussis and infant vaccinations using online surveys and follow-up semi-structured interviews. 76.3% of mothers reported safety concerns when attending healthcare settings to have their babies vaccinated, nevertheless, 94.2% agreed it was still important to get their children vaccinated during the pandemic. However, mothers from low-income households were identified as less likely to have their children vaccinated. The third Skirrow *et al.* (2024) study analysed the impact of COVID-19 on UK parents' attitudes towards routine childhood vaccines. They utilised a questionnaire survey and follow-up focus groups with parents in North-West London. Parents reported they had more questions about vaccinations due to the pandemic, but only a small minority suggested it had caused them to mistrust vaccinations.

Whilst the learning from these studies can be applied elsewhere in England, their data collection is confined to London, as was the multi-methods study by Buck *et al.* (Buck *et al.*, 2023) which evaluated the impact of COVID-19 on childhood vaccination uptake. Finally, a mixed methods study exploring parents' and guardians' views and experiences of accessing routine childhood vaccinations during the pandemic in the UK using questionnaire surveys and follow-up interviews, was published by Bell *et al.* (2020). The mixed methods inquiry found that participants from disadvantaged socioeconomic backgrounds felt an increased sense of uncertainty in booking childhood vaccination appointments and experienced greater fear of contracting coronavirus than those of an advantaged socioeconomic background. Therefore, it is already established in the literature that socioeconomically disadvantaged families experienced childhood vaccination differently during the pandemic, which was established using mixed methods. However, these commonly focus on London and parental attitudes. An alternative perspective would be to explore providers' experience in other regions of England from a post-pandemic perspective. While these studies analyse socioeconomic disadvantage, this is not their primary focus.

3.3.3. Quantitative research

Regarding wholly quantitative studies, Anderberg *et al.* (2011) explored MMR vaccine uptake. Authors identified that the “*uptake rate of the MMR declined faster in areas where a larger fraction of parents had stayed in education past the age of 18 than in areas with less educated parents*” (2011, p. 516), which was attributed to the MMR crisis 1998 (refer to Section 1.3.4, *The MMR crisis 1998*). This is further evidence of inverse associations. However, this study did not analyse the potential effects of COVID-19, unlike three other identified studies (Flatt *et al.*, 2024; Firman *et al.*, 2022; McDonald *et al.*, 2020).

McDonald *et al.* (2020) analysed the early impacts of the pandemic on the delivery and uptake of childhood vaccinations. They used life expectancy to measure health inequalities according to levels of deprivation. Authors suggested that MMR vaccination uptake declined before COVID-19 physical distancing measures were implemented. The main limitation of this study was that it only analysed uptake data from January to April 2020. However, a longitudinal study published in 2022 explored the effect of COVID-19 on the first dose of MMR in North East London and utilised the indices of multiple deprivation (IMD) to quantify socioeconomic characteristics (Firman *et al.*, 2022). The authors used the North East London Discovery Data, which found that MMR vaccination decreased by 4% overall, but children living in the most deprived areas were *more* likely to receive their vaccine on time. Similar to the identified mixed methods studies, Firman *et al.* (2022) only utilised data from London, limiting its applicability to other regions.

Lastly, a pre-print study exploring inequalities in childhood vaccination uptake in England 2019-23 using GP data and the Slope Index of Inequality (Flatt *et al.*, 2024). The authors found evidence for greater socioeconomic inequality (lower uptake for disadvantaged groups) in the uptake of the MMR vaccine than in any of the other childhood vaccines. However, this study did not explore the specific impact of certain pandemic events, or pre-pandemic uptake for comparison. Existing quantitative studies cover much ground but fail to assess the specific impact of regional differences of certain COVID-19 events and socioeconomic factors on childhood vaccination. A common focus is London, which does not represent England as a whole.

3.3.4. Summary

In summary, this literature review has clear implications for the direction of the thesis. It is evident that various aspects of socioeconomic inequalities in childhood vaccination uptake, both before and during the pandemic, have been explored. However, there are shortfalls. The mixed methods studies commonly focused on London. This may not reflect the state of uptake in other areas of England. Subsequently, there is scope for a mixed methods investigation into vaccination in other regions. The quantitative element could analyse the impact of specific COVID-19 events on childhood vaccine uptake using methods that would allow the cumulative effect to be ascertained. These findings could be used to identify a regional focus, alternative to London, for the qualitative component. The experience of vaccination service providers is lacking, as many of the qualitative studies identified explored parental attitudes. Thus, a qualitative inquiry could be undertaken with service providers to explore their experience of COVID-19 on the childhood vaccination programme. To assess the impact of socioeconomic inequalities, these providers could be sought from GP practices in socioeconomically deprived areas to maintain this lens of inequality. The appropriateness of a mixed methods methodology is discussed further in Section 3.4.4, *Mixed methods design*.

Lastly, amongst several key messages, Torracinta *et al.* (2021) were keen to enforce that socioeconomic inequalities appear to affect uptake at “each stage” of the vaccination process. However, a detailed explanation as to what they meant by “each stage” was lacking. The further development of the patient-centred access to vaccination framework created for the umbrella review and presented in Chapter 2, could simultaneously address this issue and thesis Objective 4 (Connect the findings from the umbrella review, quantitative analysis, and qualitative study to provide a comprehensive overview of socioeconomic inequalities in vaccination uptake on a global, national, and regional level). This would provide a concise overview of how socioeconomic inequalities can hinder seamless access from a service-delivery perspective.

3.4. Methodology

3.4.1. Ontology and epistemology

Declaring one's epistemological and ontological positions is crucial to any form of research. These positionalities provide context to both the methodological approach and the interpretation and discussion of findings. Ontology “*deals with what, at least in principle, can be categorized (objectified, i.e. subsumed under distinguishable categories)*” (Poli, 2010, p. 1). Thus, ontology in research concerns the concept of reality and what this implies for a researcher’s worldview (Hathcoat, Meixner and Nicholas, 2019). Within itself, immunisation can be considered a naturally occurring process involving the innate immune system, which includes barriers that prevent pathogens from entering the body, such as the skin and mucosa (Aristizábal B and Á, 2013). Indeed, immunisation can occur without human intervention, as natural immunity exists (Hahné, Farrington and Bollaerts, 2022). However, vaccination involves stimulating an immune response by introducing antigens to the body, commonly using an injection or nasal suspension. Both the specific product of this act and the act itself are the causal outcomes of human intervention. However, the phenomenon of socioeconomic inequalities in vaccination uptake is inherently a socially constructed issue, as it posits that demographical differences can affect access to this process. And, when considering that no biological or natural discrepancy exists that would cause this to occur, the topic is laden with subjectivity. Greenough *et al.* (2017) suggest that vaccination is not only a subjective issue, but its history is laden with politics by controlling the immunity of entire populations or subsets of these populations. However, the binary approach of objectivity versus subjectivity is often undesirable and antiquated. To claim that anything can be truly value-free or equally cast aside as biased for embracing the self is, in my view, of no use to research.

This thesis considers socioeconomic inequalities in vaccination uptake from a structural lens. For example, the umbrella review purposefully did not include systematic reviews that discussed attitudes and opinions towards vaccination. As well as being a highly saturated aspect of the discourse, in the context of socioeconomic inequalities, it can create a blame culture. For instance, are low levels of uptake the result of poorly

educated parents, or is it that the information being provided is inaccessible to a portion of the population? A meta-ethnography performed by Smith and Anderson (2018, pp. 165-166) on lay perspectives of health inequalities in Britain explained that individuals considered by society as of a disadvantaged socioeconomic status often did not access healthcare for fears of feeling “*judged*” and “*disrespected*”. To avoid perpetuating this unhelpful narrative, I focus on the structural barriers and the delivery of vaccination. This approach, therefore, lends itself to neither realism nor anti-realism, but critical realism.

“Critical realist ontology acknowledges the complexity inherent in social phenomena and provides a conceptual framework for describing this complexity. Descriptions of complexity, as we have illustrated, necessarily go beyond the empirical domain of reality (i.e. beyond what can be observed, experienced and measured).” (Haigh et al., 2019, p. 10)

Moreover, epistemology is “*the theory of knowledge embedded in the theoretical perspective and thereby in the methodology*” (Crotty, 1998, p. 3). Some of the key elements of epistemology were mentioned in the discussion of ontology, namely the idea of objectivity, subjectivity and constructionism (Hathcoat, Meixner and Nicholas, 2019). Hathcoat et al. states that reducing epistemology to these three concepts is somewhat of an oversimplification. However, this thesis is neither a medical nor social science project, meaning a balance must be struck between lengthy discussions of theory and real-world applications.

Mixed methods research occupies a unique position in the epistemological narrative because it operates in both the qualitative and quantitative paradigms, using their relative strengths to complement each other (Morgan, 2007). It is not as straightforward, therefore, as non-mixed methods research because the method of inquiry often predetermines the accompanying theoretical underpinnings. Morgan (2007) suggests that when paradigms are employed as epistemological stances, they are discussed in terms of compatibility. They reject this approach, believing that not only are quantitative and qualitative research commensurable but that they should be used more frequently to encourage a shift to pragmatism and away from the constraints of philosophy. The fundamental principles of the pragmatic approach are (Morgan, 2007); (1) abductivity – moving back and forth between induction and deduction; (2) intersubjectivity, recognising that true objectivity, or subjectivity, is a myth. In the pragmatic approach,

“there is no problem with asserting both that there is a single ‘realworld’ and that all individuals have their own unique interpretations of that world” (Morgan, 2007, p. 72); (3) transferability – research is neither solely context-specific nor wholly generalisable. Instead, the pragmatic approach focuses on whether the methods can be applied elsewhere.

However, there is a tension between the need to declare one’s epistemological and ontological position and the accessibility of research. Inherently, it can be viewed as an academic issue. Hathcoat and Meixner (2019, p. 113) disagree somewhat, stating that *“ontological and epistemological considerations extend well beyond ‘armchair’ philosophical debates”*, and are instead vital to research. The pragmatic approach, as the name suggests, focuses on what works best for the research topic and encourages moving away from significant entanglement in philosophy.

3.4.2. Theory

These ontological and epistemological considerations have implications for the theoretical underpinnings of this thesis, as some theories would conflict with particular worldviews. As identified in Section 3.3, *Literature Review*, there is a need to conceptualise what stages of the childhood vaccination process are affected by socioeconomic inequalities. It was suggested that this could be addressed with further development of the patient-centred access to vaccination framework used in the umbrella review (for more information, refer to Section 2.4.2, *Research Question 2*).

As suggested in Section 2.8.2, *Understanding the findings*, some of the mechanisms that systematic review authors reported contributed to the association between socioeconomic position and routine vaccination uptake did not seamlessly fit the patient-centred access to vaccination framework. For instance, “vaccine delivery strategy (facility versus school-based)” (Gallagher *et al.*, 2016; Murfin *et al.*, 2020) and “Ease of access based on the healthcare system” (Nagata *et al.*, 2013; Okoli *et al.*, 2020; Forshaw *et al.*, 2017) are often decided by powers greater than the vaccination provider and thus represent a policy issue. Additionally, the framework made no direct reference to socioeconomic position and other potentially influential demographical determinants, such as gender and ethnicity. Subsequently, adaptations were required in

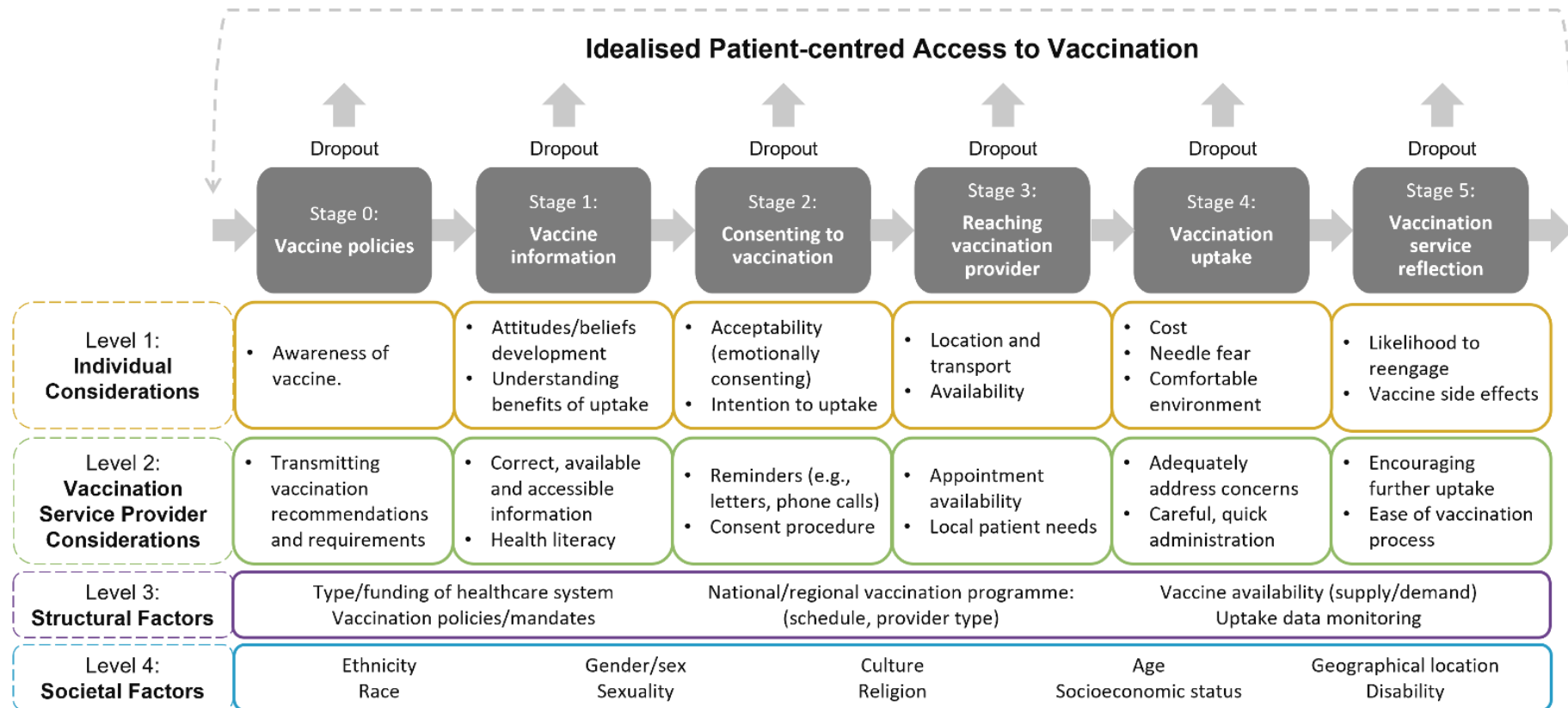
light of these shortfalls, such as the inclusion of “structural factors” and “societal factors” levels. The framework began to echo the Socio-ecological Model of Health during this process, which was subsequently embraced. Another motivation for employing the socio-ecological model was its synergies with the critical-realist worldview and pragmatic epistemology, all of which posit that there is no singular “true” perspective. The Socioecological Model of Health is discussed in Section 1.2.1, *The Socio-ecological Model of Health and healthcare inequalities*.

The Socioecological Model of Health has already been successfully applied to vaccination, but these are often related to hesitancy and acceptance (Alabadi, Pitt and Aldawood, 2023; Lun *et al.*, 2022; Olaniyan, Isiguzo and Hawk, 2021). My framework attempts to capture childhood vaccination uptake as a process, meaning it differs slightly. Two additional levels were introduced to the patient-centred framework, as illustrated in Figure 3.1: “Structural factors” refer to the following issues: type/funding of healthcare system; vaccination policies/mandates; national/regional vaccination programme (schedule and provider type); vaccine availability (supply/demand); uptake data monitoring. “Societal factors” incorporate the socioeconomic position alongside other influential demographical characteristics. They are placed at level 4 to enforce that these factors operate beyond the control of the vaccination process; as stated in Section 1.2.2, *Socioeconomic inequality in health and healthcare*, socioeconomic inequality is “both structurally imposed and socially produced, with the resulting inequalities in people’s positions woven into the of their daily lives” (Graham, 2007, p. 36).

Section 2.8.2, *Understanding the findings*, also suggested that the framework does not accurately capture the importance of vaccination information and subsequent knowledge development. Thus, stages 0 and 1 were altered to reflect this. Lastly, the terms relating to the between-stage mediators, such as “Approachability” and “Ability/likelihood to approach”, were removed because they were too restrictive. For instance, “Affordability” and “Ability/likelihood to pay” do not apply to countries where vaccinations are provided free by the healthcare system, such as England, which the remainder of this thesis focuses on. Any further alterations were made for improved clarity. The framework is returned to in Chapter 6, where it is used to map the findings of the mixed methods study, informing its final iteration.

Figure 3.1

Illustrates the patient-centred access to vaccination framework (version 2).



3.4.3. Reflexivity

On the subject of worldviews and theory, another related concept to consider is reflexivity. This teaches researchers to acknowledge and state their biases when conducting qualitative research because they are products of their environment, much like the Socioecological Model of Health suggests.

“Reflexivity is a set of continuous, collaborative, and multifaceted practices through which researchers self-consciously critique, appraise, and evaluate how their subjectivity and context influence the research processes.” (Olmos-Vega et al., 2023, p. 242)

There are various types of reflexivity related to different elements of the research process (Finlay, 2002), such as personal reflexivity, where the researcher addresses how their unique perspective may influence the study (Olmos-Vega et al., 2023). For instance, I came to this PhD project with a social science background, and therefore, I often emphasise the importance of the social context in which the research project sits, evidenced by the use of the Socioecological Model of Health framework. I take the stance that socioeconomic inequalities in vaccination uptake are not the fault of the individual but are a reflection of their environment. I also harbour positive attitudes towards vaccination and have received all those that are freely available through the NHS.

Whilst reflexivity stems from the social sciences, with the increase in qualitative methods employed in health research, it is becoming more relevant (Allan and Arber, 2018). In the data collection and interpretation of the findings, I must recognise I will view them in a certain light. This is a fact, and one despite my best efforts to minimise my perspective.

“We accept that the researcher is a central figure who influences, if not actively constructs, the collection, selection and interpretation of data. We recognize that research is co-constituted, a joint product of the participants, researcher and their relationship. We understand that meanings are negotiated within particular social contexts so that another researcher will unfold a different story. We no longer seek to eradicate the researcher’s presence – instead subjectivity in research is transformed from a problem to an opportunity.” (Finlay, 2002, p. 212).

For instance, the interpretation of the empirical data may be different if I held anti-vaccination views.

3.4.4. Mixed methods design

Fundamentally, mixed-methods research combines both the qualitative and quantitative paradigms into one project to complement one another. There are various ways this can be done. It is important to distinguish this from multi-methods, where the qualitative and quantitative data collection and subsequent analysis are separate entities. Creswell *et al.* (2011, p. 4) define mixed methods as a research methodology:

- focusing on research questions that call for real-life contextual understandings, multi-level perspectives, and cultural influences;
- employing rigorous quantitative research assessing magnitude and frequency of constructs and rigorous qualitative research exploring the meaning and understanding of constructs;
- utilizing multiple methods (E.g., intervention trials and in-depth interviews);
- intentionally integrating or combining these methods to draw on the strengths of each; and
- framing the investigation within philosophical and theoretical positions.

Mixed methods utilise convergence and sequential approaches to bring together both types of inquiry. These are briefly described in Table 3.2. Creswell and Plano Clark (2017) suggest that other researchers may refer to these designs using different terminology, but the underlying principles are the same; such as using “triangulation” instead of “convergent”. The type and variation of the mixed methods model depends on the research aims and the underpinning theoretical considerations.

Table 3.2

The three main types of mixed methods design and their variations, informed by Creswell and Plano Clark (2017).

Mixed methods design Variants	Description
Parallel convergent	
<i>Parallel-databases variant.</i>	Utilises two different, complementary methods (quantitative and qualitative). The data collection occurs separately in no specific order, and the findings are brought together afterwards, where they seek to obtain a complete understanding of the research topic.
<i>Data-transformation variant.</i>	
<i>Questionnaire variant.</i>	
<i>Fully-integrated variant.</i>	

Sequential explanatory	
Follow-up explanations variant.	The quantitative data collection and analysis occurs first, followed by the qualitative data collection and analysis. The primary aim of this design is for the qualitative component to explain or investigate the quantitative findings.
Case-selection variant.	
Sequential exploratory	
New-variable development variant.	The qualitative data collection and analysis occurs first, followed by the quantitative data collection and analysis. The quantitative findings could be used to test the qualitative findings or inform the inclusion of a specific variable.
Survey-development variant.	
Intervention-development variant.	
Digital tool development variant.	

Mixed methods research is especially applicable to the health science discipline, especially when exploring inequalities because it bridges the gap between medical and social sciences (Creswell *et al.*, 2011). For instance, the quantitative aspect can assess the effectiveness of a medical treatment, and the qualitative can explore the patient and service providers' experience of receiving and delivering the treatment. The results can then be integrated to provide a comprehensive overview of the treatment to ascertain its success.

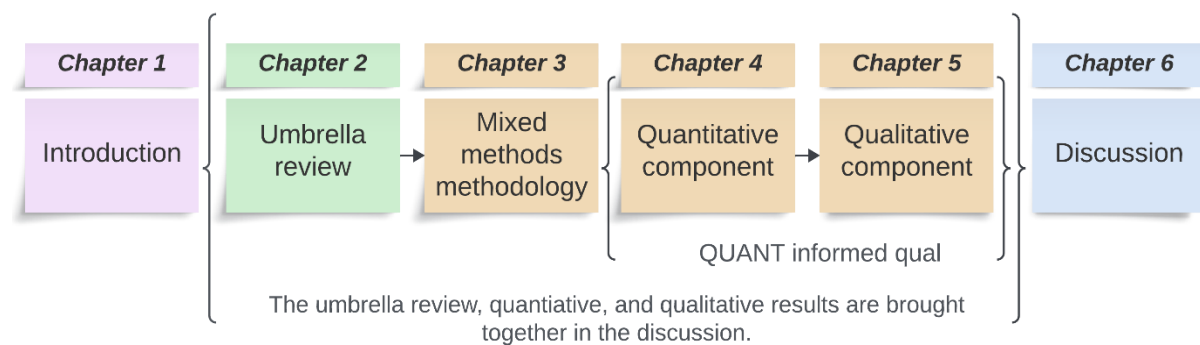
Indeed, there are drawbacks to conducting mixed-methods research. The most notable is the workload (McBride *et al.*, 2019). Both components generate lots of data, which must be analysed and integrated logically and effectively. This requires two distinct methodological approaches but must not be wholly dissimilar to prevent integration. There is also an alleged paradigm incompatibility (Tariq and Woodman, 2013). This incompatibility was discussed in Section 3.4.1, *Ontology and epistemology*. Undertaking a true mixed methods, and not simply a multi-methods, study is not an easy feat, and the success of such a project can depend on the skill of the researcher (Tariq and Woodman, 2013; Meixner and Hathcoat, 2019).

Moreover, several methods can comprise the quantitative and qualitative components, dependent on the research aims and objectives, theoretical implications and practical considerations (Baran, 2020; Creswell *et al.*, 2011; McBride *et al.*, 2019; Meixner and Hathcoat, 2019; Morgan, 2007; Tariq and Woodman, 2013; Tashakkori and Teddlie, 2003).

As ascertained in Section 3.3, *Literature Review*, there is a research gap relating to the cumulative impact of COVID-19 events on childhood vaccination uptake, specifically in regions other than London. It was suggested that the quantitative inquiry could identify a region on which to focus the qualitative component. Subsequently, this lent itself to a sequential explanatory design. Figure 3.2 provides a visual explanation of the design and its position in the thesis. This mixed methods project utilised both the follow-up explanation and case-selection variant of the explanatory sequential design; the follow-up explanation variant uses the “*qualitative phase to help explain the quantitative*” (Creswell, 2017, p. 82), and the case-selection variant, uses “*initial quantitative results to identify and purposefully select the best participants*” (Creswell, 2017, p. 82).

Figure 3.2

A diagram depicting the exploratory sequential mixed methods design employed in this thesis.



It was evident that the identified mixed methods studies used survey questionnaires or routinely collected uptake data for their quantitative component and interviews or focus groups for the qualitative. Most wholly quantitative studies analysed routinely collected data, albeit using different statistical methods. To compare childhood vaccination uptake across regions, a secondary analysis of routinely collected data is the most appropriate method. Most prominently, this is because time-series data is required to analyse the impact of COVID-19. The routine data analysis is referred to as descriptive epidemiology; “*the study of variations in measures of population health by time, person, and place*” (Bruce, Pope and Stanistreet, 2017, p. 33). The different types of routinely collected childhood vaccination uptake data are discussed in Chapter 4. Routine data is most useful for population studies because, although not always accurate, it is often the best representation of the phenomena under study (Bruce, Pope and Stanistreet, 2017).

One drawback is that the researcher does not control the information collected, such as useful demographics, which could be used as covariates in statistical analysis (Bruce, Pope and Stanistreet, 2017).

Regarding the qualitative method, only studies exploring parental attitudes were identified. Thus, an alternative perspective would be a unique contribution to the literature, such as those involved in delivering, commissioning, supporting, and monitoring the childhood vaccination programme. To achieve this, the method needed to enable cross-profession comparisons whilst ensuring the data collection process was consistent. Interviews are an appropriate method for doing this. Interviews seek interviewees' personal accounts and experiences and allow specific questions to be asked on a given topic (Liamputtong, 2019). In the context of mixed methods, this meant direct follow-up questions could be asked about the quantitative study outcomes. The drawback of interviews and much qualitative research is that their success often depends on the interviewer's personal skills and capabilities (Nathan, Newman and Lancaster, 2019).

3.4.5. Conclusion

This chapter has successfully utilised the findings of the umbrella review and the existing literature to narrow the scope of the thesis. A gap in the discourse regarding a mixed-methods inquiry into the childhood vaccination programme from a delivery perspective, focusing on areas of high socioeconomic deprivation and the COVID-19 pandemic. It was further identified that a regional focus alternative to London would provide a new perspective. A mixed methods approach was the most appropriate, as the quantitative element could be used to identify an alternate regional focus for the qualitative element.

Then, it was explained how a critical realist worldview, with a pragmatist epistemology, was the most suitable for the study in combination with the Socioecological Model of Health as the guiding theory. Afterwards, the patient-centred access to vaccination framework was adapted, informed by the Socioecological Model of Health, before briefly discussing the issue of reflexivity in research. To finish, it was ascertained that an explanatory sequential mixed methods design was best to integrate the qualitative and quantitative components; these are a statistical analysis of routine childhood

vaccination uptake data and interviews with professionals involved in delivering the childhood vaccination programme.

Chapters 4 and 5 present the quantitative and qualitative components (respectively) of the mixed methods study, which aims to comprehensively understand the narrative and state of socioeconomic inequalities in vaccination uptake in a post-COVID-19 era.

Chapter 4. **Analysing the Effect of COVID-19 on Socioeconomic Inequalities in Childhood Vaccination Uptake in England: A Piecewise Regression.**

4.1. Introduction

4.1.1. Chapter overview

In Chapter 3, a gap in the existing literature was identified. Namely, that an exploration into the impact of COVID-19 and deprivation on childhood vaccination uptake would be a beneficial contribution to the discourse. Thus, Chapter 4 performs a statistical analysis of the interaction between deprivation and COVID-19 on area-level childhood vaccination uptake using piecewise regressions. This represents the quantitative component of the mixed methods study and addresses the second thesis objective as follows:

Objective 2 – Quantitatively analyse whether there has been a change in socioeconomic inequalities in childhood vaccination uptake in England associated with the COVID-19 pandemic.

Firstly, the different types of data available are discussed before outlining the operationalisation of the variables used in the analysis. Afterwards, the statistical methods, hypotheses, and model specifications are presented. An exploratory analysis is then performed to justify a narrowed focus on two childhood vaccines. Following this, the results of the main analyses are presented, including various tests of robustness. To conclude, the findings in relation to the hypotheses are summarised, including the limitations of the approach, and the implications of these findings for the qualitative interview study are discussed (Chapter 5).

4.2. Data

4.2.1. Vaccination uptake data

As time series data is required to analyse the effect of COVID-19 on socioeconomic inequalities in childhood vaccination uptake, sources must be available for several years. The two main sources are the routinely published Cover of Vaccinations Evaluated Rapidly (COVER) and the Clinical Practice Research Datalink (CPRD). COVER data are considered official statistics – a written report accompanies the datasets, and both are freely available to download from the NHS Digital website. GP practices share their uptake statistics with their local Child Health Information Services (CHIS) team, of which there are several across England. CHIS are:

“Local active clinical care records of all the children in an area, ideally containing information about an individual child's public health interventions, particularly screening, immunisations and outcomes of the 0 to 5 healthy child programme (including the mandated review points), and where relevant information for use in the safeguarding of children.” (Local Government Association, 2024a)

Every CHIS is commissioned and managed by their regional NHS England team. For more information on the English healthcare system, refer to Section 3.2.1, *The English healthcare system*. Each of the CHISs submits the GP data to COVER. Appendix 4.1 illustrates the complexity of this process and the rigorous checking procedures before publication. There can be some minor issues with the integrity of COVER data because it relies on the accurate execution of multiple steps and the seamless transference of data from GP practices to CHIS and then CHIS to COVER (Amirthalingam, White and Ramsay, 2012). The role of CHIS is discussed further in Chapter 5.

COVER is published annually and quarterly. The publications follow the financial year, E.g., October – December 2023 is the third quarter of the 2023-2024 financial year. Statistics are provided at various levels of geographical granularity, including local authorities, regions, and other healthcare-related classifications, such as (former) Strategic Health Authorities. The healthcare-related classifications differ based on the changing landscape of English healthcare provision (refer to Section 3.2.1, *The English healthcare system*, for more information). Each publication provides the number of children vaccinated for each vaccine, including the total number of children eligible in

each cohort. The data are available to download in various file formats, such as comma-separated values (CSV) and Excel.

COVER data is not published in the quarter following the recording of uptake and instead reflects the quarters in which each cohort reached their first, second, and fifth birthday, known as the “evaluation quarter”. For example, the children who reached their fifth birthday in October – December 2023, the third quarter of the 2023-2024 financial year, would have received their pre-school booster 20 months beforehand. The uptake of individual doses is not provided for most vaccines. Instead, the statistics reflect completed courses of all doses. Table 4.1 illustrates when the uptake data for all childhood vaccinations are published.

On the other hand, the CPRD provides anonymised patient data at the GP level. It is hosted by the Medicines & Healthcare Products Regulatory Agency (2024), accessible only via a paid subscription and subject to project approval. Successful approval provides researchers access to the CPRD database to search for relevant Systematized Nomenclature of Medicine (SNOMED) codes to extract the associated data. For instance, each vaccine has a SNOMED code; after uptake has occurred, it is attached to a child’s record. Linkages can also be requested, such as using the patient’s postcode to identify the Lower-layer Super Output Area (LSOA) and subsequent Indices of Multiple Deprivation (IMD) decile. GP practices must opt-in for their data to be included in the CPRD, and this does not include patients who have opted out of data sharing (Herrett *et al.*, 2015). Subsequently, it does not hold data on every member of the UK population.

4.2.2. COVER and CPRD: strengths and limitations

Both data sources have strengths and limitations. One strength of the CPRD data is that it is provided at the individual level. In contrast, COVER is aggregated, which can produce issues of ecological fallacy: “*inherent in making causal inferences from group data to individual-level behaviours*” (Schwartz, 1994, p. 819). Schwartz *et al.* suggest that substituting group-level variables for individual-level variables can inflate the risk of omitted variable bias as the parameters have shifted. However, a quantitative study explored sociodemographic and geographic variation in HPV vaccination in Minnesota (Finney Rutten *et al.*, 2017). Finney Rutten *et al.* used the Rochester Epidemiology Project

data to ascertain uptake, and socioeconomic data from the American Community Survey. The research found that a disadvantaged socioeconomic position was associated with lower initiation rates and completion of the second and third doses. The authors also identified that, in the eastern region and the greater Rochester metropolitan area, increased odds of Human Papillomavirus (HPV) vaccination uptake that was not explained by the individual-level data. This demonstrates the usefulness of analysing uptake data at the area level, as it can aid in understanding why trends are seen in specific locations.

However, unlike the CPRD, opting out of COVER is not possible as it is a national statistic used for monitoring communicable diseases (NHS England, 2024c); this suggests that the data may better reflect the entire population. Although recent research suggests accurate childhood vaccination uptake statistics can be produced using the CPRD (Suffel *et al.*, 2023). Nevertheless, COVER endures rigorous verification procedures before publication, whereas the CPRD requires data mining and the identification of relevant SNOMED codes, which exposes the process to human error. It is unclear whether a sole researcher could achieve high levels of accuracy using CPRD and how much time this would consume. This is an additional concern when considering time-series data is required. COVER's ease of access is a significant strength over the CPRD, as the data are freely available and provided in straightforward formats. Thus, COVER data was used for this analysis because it incurs less accuracy risk.

As outlined in Table 4.1, there are fourteen combinations of vaccines and reporting intervals that could be analysed. In view of this, an exploratory analysis was performed to identify a smaller group of vaccines to investigate further, the results of which are presented in the findings section.

Table 4.1

The 0-5 childhood vaccinations and when the uptake statistics are published for each vaccine.

Vaccine	Antigen(s)	Age administered	Dose(s)	Evaluation period		
				12m	24m	5yr
6-in-1 vaccine (DTaP/IPV/Hib/HepB)	Diphtheria, Tetanus, Pertussis (DTaP), polio (IPV), Haemophilus influenzae type B (Hib), and Hepatitis B (HepB).	8 weeks	1 st of 3	x	x	x
		12 weeks	2 nd of 3			
		16 weeks	3 rd of 3			
Rotavirus vaccine (Rota)	Rotavirus	8 weeks	1 st of 2	x		
		12 weeks	2 nd of 2			
MenB vaccine (MenB)	Meningitis B	8 weeks	1 st of 3	x	x	
		16 weeks	2 nd of 3			
		1 year	3 rd of 3			
Pneumococcal vaccine (PCV)	Pneumococcus	12 weeks	1 st of 2	x	x	
		1 year	2 nd of 2			
Hib/MenC vaccine (Hib/MenC)	Haemophilus influenzae type B (Hib), Meningitis C (MenC)	1 year	1 st of 1		x	x
MMR vaccine (MMR)	Measles, mumps, and rubella	1 year	1 st of 2		x	x
		3 years, 4 months	2 nd of 2			x
4-in-1 pre-school booster vaccine	Diphtheria, Tetanus, Pertussis (DTaP), polio (IPV)	3 years, 4 months	1 st of 1			x

4.2.3. Socioeconomic position

There are several approaches to quantifying socioeconomic position. As explored in Section 1.2.2, *Socioeconomic inequality in health and healthcare*, socioeconomic position is commonly measured using one of the following indicators: occupation (employment/unemployment), income (wealth), education, deprivation (poverty), social capital and human capital, socioeconomic class, and socioeconomic status. Additionally, in Section 2.3.3, *Inclusion and exclusion criteria*, it was suggested that occupation (employment/unemployment), income (wealth), education, and deprivation (poverty) are most easily quantified. As the COVER vaccination uptake data is aggregated, the socioeconomic position measure must apply to the area level. Thus, deprivation was the most appropriate, such as the English Indices of Deprivation (IoD) or the Townsend Deprivation Index, which would capture the socioeconomic environment best.

The Townsend Deprivation Index is generated using census data of four indicators: households without a car, overcrowded households, households not owner-occupied, and persons unemployed (Townsend, Phillimore and Beattie, 2023). This is useful when analysing earlier trends because it is available from 1971 to 2011, whereas the IMD is available from 2004 to 2019. The English IoD 2019 provides measures of deprivation at LSOA, which is a collection of 400 to 1,200 households (Ministry of Housing, 2019b). The IoD emphasises the key distinction between poverty and deprivation; poverty refers to a lack of finances, affecting what can be afforded. However, deprivation is not financially centred and instead can refer to a lack of ownership or access to resources (Ministry of Housing, 2019a). The IoD refers to these individual resources as “indicators” that are assigned to one of seven groups. These groupings are known as “domains”. A detailed breakdown of all domains is presented in Table 4.2.

The domains can be used individually or as a composite measure, the IMD. For the IMD, each of the seven domains is weighted differently, as represented in Table 4.2, to provide an overall measure of deprivation for an LSOA. However, it is recognised that the most recent IMD was published in 2019 and, therefore, does not account for recent changes in deprivation. Considering that the IMD is calculated using several different indicators,

unlike the Townsend Index, which only includes four, the IMD was selected for analysis. This provides a more comprehensive overview of socioeconomic deprivation.

Table 4.2

2019 English Indices of Deprivation domains and indicators (Ministry of Housing, 2019b, p. 16).

Domain (n = 7)	Indicators (n = 39)	
Income deprivation (22.5%)	- Adults and children in income-support families - Adults and children in income-based jobseekers allowance families - Adults and children in income-based employment and support allowance families - Adults and children in pension credit (guarantee) families	- Adults and children in working tax credit and child tax credit families below 60% median income not already counted - Asylum seekers in England in receipt of subsistence support, accommodation support, or both - Adults and children in universal credit families where no adult is in 'working – no requirements' conditionality regime
Employment deprivation (22.5%)	- Claimants of jobseekers allowance, aged 18-59/64 - Claimants of employment and support allowance, aged 18-59/64 - Claimants of incapacity benefit, aged 18-59/64 - Claimants of severe disablement allowance, aged 18-59/64	- Claimants of carers allowance, aged 18-59/64 - Claimants of universal credit in the 'searching for work' and 'no work requirements' conditionality groups, aged 18-59/64
Education, skills, and training deprivation (13.5%)	Children and young people: - Key stage 2 attainment: scaled scores - Key stage 4 attainment: average capped points score - Secondary school absence - Staying on in education post-16 - Entry to higher education	Adult skills: - Adults with no or low qualifications, aged 25-59/64 - Adults who cannot speak English, or cannot speak English well, ages 25-59/64
Health deprivation and disability (13.5%)	- Years of potential life lost - Comparative illness and disability ratio	- Acute morbidity - Mood and anxiety disorders

Crime (9.3%)	Recorded crime rates for: • Violence • Burglary	• Theft • Criminal damage
Barriers to housing and services (9.3%)	Geographical barriers: Road distance to a: • Post office • Primary school • General store or supermarket	Wider barriers: • Household overcrowding • Homelessness • Housing affordability
Living environment deprivation (9.3%)	Indoor living environment: • Houses without central heating • Housing in poor condition	Outdoor living environment: • Air quality • Road traffic accidents
% = weighting of each domain in the Indices of Multiple Deprivation (IMD)		

Local authority-level data was selected to ensure the geographical granularity of the vaccination uptake statistics and IMD converged. For the IMD, LSOAs can be aggregated to higher levels of geography, such as Local Authority Districts, upper tier Local Authorities, and Local Enterprise Partnerships (Ministry of Housing, 2019b). The COVER vaccination uptake data used for this analysis is provided at an upper-tier local authority level; thus, the same geographical granularity for the IMD was used. Many different summary measures of IMD are produced at the local authority level (Ministry of Housing, 2019b, pp. 24-26), such as:

- **Average rank** - summarises the average level of deprivation across the higher-level area, based on the ranks of the Lower-layer Super Output Areas in the area.
- **Average score** - summarises the average level of deprivation across the higher-level area, based on the scores of the Lower-layer Super Output Areas in the area.
- **Proportion of LSOAs in most deprived 10% nationally** – By contrast to the ‘average rank’ and ‘average score’ measures, which are based on all LSOAs in the higher-level area, this measure focuses only on the most deprived LSOAs.
- **Extent** – a summary of the proportion of the local population that live in areas classified as among the most deprived in the country.
- **Local concentration** - a summary of how the most deprived LSOAs in the higher-level area compared to those in other areas across the country.

The “proportion of LSOAs areas in most deprived 10% nationally”, “extent”, and “local concentration” measures focus on areas of deprivation and, thus, do not provide an overview of the less-deprived areas, which is not useful for this study. “Average rank” and “average score” are similar, but “average score” can be skewed by local authorities that have a greater proportion of polarisation (Ministry of Housing, 2019b). “Average rank” is more robust to this, as it is calculated using an average of LSOAs, which reduces the influence of extremities. Therefore, the “average rank” for this study was used. “Average rank” is also provided in a ranked version – “rank of average rank” – which simplifies the interpretation by assigning a number 1 to 151 and was selected for ease.

4.3. Methods

4.3.1. Data cleaning

This analysis used the quarterly publications of COVER for the main analysis to increase the number of observations and to explore the impact of COVID-19 more accurately. However, the most recent annual COVER publication (2022-23 financial year) was utilised in the exploratory investigation to provide an overview of uptake. This ensures that a poorly performing quarter did not bias the selection of vaccines for the main analysis and instead reflects longer-term trends. Before 2012, quarterly uptake was not published at the local authority level, only by Primary Care Trust. Between 2012 and 2016, this local authority data was considered experimental. Data is considered experimental in its infancy, meaning there could be accuracy issues. Thus, a cutoff of 2016 to the present day was selected as the timeframe for analysis. There were 32 time points in total, from April – June 2016 to January – March 2024, which reflect vaccines administered 6 or 7 quarters prior, meaning the timeframe is July – September 2014 to April – June 2022. This provides 31 observation points, as the data for the April-June 2021 evaluation quarter has not been published; the reason for this is unclear. Although, it can be considered Missing at Random (MAR). MAR means the absence of the data does not dictate the likelihood of the outcome and, thus, is not an issue (Molenberghs and Kenward, 2007). Unpopulated cells were included in the analysis to reflect the time trends more accurately. A table mapping the administration and evaluation quarters can be viewed in Appendix 4.2.

Uptake was calculated by dividing the eligible population of a local authority by the number of children vaccinated. Given the large sample size which accompanies analysing national data, the resulting proportions can be approximated by a normal distribution. Thus, the analysis treated the outcome variable as continuous, leveraging the benefits of continuous data methods for simplicity and interpretability rather than using binomial or count data methods.

There were some instances of missing uptake data for local authorities for various reasons, which are included in a caveat table in each quarterly publication. Occasionally, there is no available information on the population that is not registered with a GP to calculate the uptake statistics, meaning the denominator is those who are registered at the GP practice, which can slightly inflate the uptake percentages if there are unregistered children in the area. The data caveats can be viewed in Appendix 4.3 and will be considered when interpreting the results of the statistical tests.

Over time, some local authorities have changed their boundaries, meaning that not all 32 COVER datasets could be combined without alteration. There are three main changes:

- In the financial year 2016-2017, the City of London was reported as an individual local authority, but it was combined with Hackney in the remaining publications. Therefore, from the 2017-2018 financial year to 2023-2024, the data for Hackney and the City of London were combined.
- From the financial year of 2016-2017 until 2018-2019, Bournemouth and Poole were reported separately, but they were combined in the remaining publications. Thus, from the 2019-2020 financial year to 2023-2024, the data for Bournemouth and Poole were combined.
- From the financial year of 2016-2017 to the second quintile of 2021-2022, West and North Northamptonshire were reported as one local authority. Beyond this date, they were reportedly separately. Subsequently, the data for West and North Northampton were combined from the third quintile of the 2021-2022 financial year to 2023-2024.

Additionally, one alteration was made regarding the IMD. In the COVER publications, the City of London and Hackney uptake statistics are combined, but in IMD, they are separate. To preserve the original order of the deprivation scores, the City of London was removed, and the Hackney IMD score represents the two areas. The information was then re-ranked, resulting in those of a lower rank moving up one position. The data cleaning process meant 150 local authorities were analysed consistently across 32 time points, with one quarter missing (April-June 2021), resulting in 4,650 observations.

When time-series (COVER uptake statistics) and cross-sectional (IMD rank of average rank) data are combined, this is known as panel data.

“Panel data or longitudinal data typically refer to data containing time series observations of a number of individuals. Therefore, observations in panel data involve at least two dimensions; a cross-sectional dimension, indicated by subscript i , and a time series dimension, indicated by subscript t .” (Hsiao, 2007, p. 1)

Statistical methods must, therefore, account for these repeated observations. One strength of using panel data methods, such as fixed effects, is that they can help reduce omitted variable bias by controlling for unobserved time-invariant variables (Hsiao, 2007). Balestra and Nerlove (1966) are credited for spurring the development of modern econometric methods using panel data (Hsiao, 2007).

4.3.2. Piecewise regression

The objective of this quantitative analysis was to ascertain whether there has been a change in socioeconomic inequalities in childhood vaccination uptake in England associated with the COVID-19 pandemic. There are many different approaches to this, such as linear probability modelling (Iusitini, Pacheco and Schober, 2024), but this thesis utilises piecewise terms. Bernal *et al.* (2017) state that similar methods are becoming increasingly popular to test the impact of policies or interventions at a population level. This is because of their ability to clearly define a breakpoint where the outcome is expected to change. To ascertain whether this approach is appropriate, researchers should consider their research questions and perform an exploratory analysis to understand the distribution of their data. The approach to this analysis was also guided by other work employing this method in similar contexts (Bennett *et al.*, 2024), especially *Exploring the impact of the English national health inequalities strategy on infant mortality*

(Bennett *et al.*, 2024), and *The impact of New Labour's English health inequalities strategy on infant mortality* (Robinson *et al.*, 2019).

To use a piecewise regression, potential breakpoints where COVID-19 may have impacted uptake in childhood vaccination needed to be identified. For illustration, a brief overview of some of the key events from the COVID-19 pandemic in England is provided in Figure 4.1. The first breakpoint investigated was the first lockdown. This signifies the beginning of restrictions placed on individual liberties and, thus, the ability to access childhood vaccination services. As the first lockdown came into effect at the end of a financial quarter (January – March 2020), the following quarter (April – June 2020) was used as the breakpoint to account for a lag in impact. Still, a robustness test was performed to ascertain the impact of this decision. Unlike the two examples provided that use piecewise regression (Robinson *et al.*, 2019; Bennett *et al.*, 2024), the pandemic does not have a clear endpoint. Subsequently, this is not included in the analyses.

Considering this project concerns vaccinations, it would be pertinent to ascertain whether the rollout of COVID-19 vaccinations impacted childhood vaccination uptake. The majority of the English population received their COVID-19 vaccination in two phases, as follows:

- Phase 1 began on 8th December 2020 with vaccination rollout for priority groups 1-9 – all those over 50 years old, clinically at-risk individuals, and front-line health and social care workers.
- Phase 2 began on 13th April 2021 – 18-49-year-olds in descending age order.

As with the first lockdown, a lagged version of the Phase 1 vaccination rollout was used because it occurs towards the end of the quarter; a robustness test is also conducted without this lag. In Section 3.1.2, *Narrowing the scope*, “spillover” effects on the uptake and perception of other childhood vaccines were identified as a result of the 1998 MMR crisis (Anderberg, Chevalier and Wadsworth, 2011). Phase 2 rollout coincided with advice from the JCVI pertaining to an increased risk of blood clots found in those who had received the Astra Zeneca vaccine, a risk which decreases with age (refer to Figure 4.1). This could lead to an increase in general vaccine hesitancy and subsequently impact

childhood vaccination uptake. Especially as those who were receiving the COVID-19 vaccinations in Phase 1 and Phase 2 were the childhood vaccination decision-makers.

Figure 4.1

A timeline of the key events from the COVID-19 pandemic in England.

2020		
	29th January	First two patients test positive.
	23rd March	First national lockdown initiated.
	5th November	Second national lockdown initiated.
	8th December	Vaccination rollout for priority groups 1-9 (Phase one) begins – all those over 50-years-old, clinically at-risk individuals, and front-line health and social care workers.
		18th December (w/e) to 15th May 2021 (w/e) – Alpha variant dominant.
2021		
	6th January	Third national lockdown initiated.
	7th April	JCVI recommend under 30-year-olds have alternative vaccines to Astra Zeneca due to increased risk of blood clots.
	13th April	Vaccination rollout for 18-49-year-olds (Phase two) begins in descending age order
	7th May	JCVI recommend under 40-year-olds have alternative vaccines to Astra Zeneca due to increased risk of blood clots.
		22nd May (w/e) to 19th December 2021 (w/e) – Delta variants dominant.
	5th August	Vaccination rollout for all 16-17-year-olds.
	16th September	Booster programme rollout (third Covid-19 vaccination), beginning with Phase one priority groups.
	20th September	Vaccination rollout for all 12-15-year-olds.
		23rd December (w/e) to 5th September 2022 (w/e) – Omicron variants dominant.
2022		
	31st January	Vaccination rollout clinically at-risk 5-11-year-olds or those who live with someone who is immunosuppressed.
	13th February	43,643,196 people had received at least one Covid-19 vaccination.
w/e = week ending; JCVI = Joint Committee on Vaccinations and Immunisations		

4.3.3. Hypotheses and model specification

The hypotheses for the analysis were as follows:

Hypothesis 1

H₀: There are no changes in 0-5 childhood vaccination uptake from September 2014 to March 2022.

H₁: There are changes in 0-5 childhood vaccination uptake from September 2014 to March 2022.

Hypothesis 2

H₀: The change in 0-5 vaccination uptake during the COVID-19 pandemic is not affected by the deprivation level of a local authority.

H₁: The change in 0-5 vaccination uptake during the COVID-19 pandemic is affected by the deprivation level of a local authority.

Hypothesis three

H₀: The change in 0-5 vaccination uptake during the COVID-19 pandemic associated with the deprivation level of a local authority does not differ across regions.

H₁: The change in 0-5 vaccination uptake during the COVID-19 pandemic associated with the deprivation level of a local authority differs across regions.

Hypothesis 1 is exploratory and sought to identify whether there were any changes in 0-5 childhood vaccination uptake. Hypothesis 2 aimed to address thesis Objective 2 (Quantitatively analyse whether there has been a change in socioeconomic inequalities in childhood vaccination uptake in England associated with the COVID-19 pandemic). Hypothesis 3 attempted to probe this change further. As the second hypothesis primarily addresses thesis Objective 2, the model specification is illustrated below in **Formula 4.1**. The model specification for Hypothesis 3 can be viewed in Appendix 4.4.

Formula 4.1

$$\begin{aligned}
 Uptake_{LA,t} = & a_0 + \beta_1 t_1 + \beta_2 t_2 + \beta_3 t_3 + \beta_4 DepQuint_1 * t_1 + \beta_5 DepQuint_2 * t_1 \\
 & + \beta_6 DepQuint_4 * t_1 + \beta_7 DepQuint_5 * t_1 + \beta_8 DepQuint_1 * t_2 \\
 & + \beta_9 DepQuint_2 * t_2 + \beta_{10} DepQuint_4 * t_2 + \beta_{11} DepQuint_5 * t_2 \\
 & + \beta_{12} DepQuint_1 * t_3 + \beta_{13} DepQuint_3 * t_3 + \beta_{14} DepQuint_4 * t_3 \\
 & + \beta_{15} DepQuint_5 * t_3 + u_{LA} + \varepsilon_{LA,t}
 \end{aligned}$$

Where $Uptake_{LA,t}$ is the proportion of eligible children vaccinated in a local authority LA at time t . a_0 is the constant term, and t_1 , t_2 , and t_3 are the piecewise terms representing the quarterly trends from the lagged effect of the first lockdown, lagged effect of Phase 1 COVID-19 vaccination rollout, and Phase 2, respectively. $DepQuint_1$, $DepQuint_2$, $DepQuint_4$, and $DepQuint_5$ indicate the deprivation quintile of LA according to the 2019 Indices of Multiple Deprivation. u_{LA} and $\varepsilon_{LA,t}$ are both error terms. u_{LA} is the local authority time invariant local error term, and $\varepsilon_{LA,t}$ is the idiosyncratic random error term. The model includes the main effects of the three piecewise terms, t_1 , t_2 , and t_3 , but not for $DepQuint$, because the panel structure absorbs them. A control variable is included ($nChild$), representing the number of vaccination-eligible children in a local authority at each time point. This inclusion controls for population size effects. Table 4.3 displays all variables used in the main models.

Further tests were performed to assess the robustness of the models, such as:

- Interchanging fixed effects for random effects.
- Using different operationalisations of deprivation, E.g., continuous and deciles.
- Specifying different piecewise terms.
- Performing the analysis both with and without potential outliers.

The primary assumptions of panel regression are normality of residuals, autocorrelation and heteroskedasticity, which are explored using diagnostics. Nevertheless, robust standard errors clustered by local authority accounted for potential autocorrelation and heteroskedasticity, ensuring a more reliable interpretation of the coefficients.

To perform this analysis in RStudio (Posit Software, 2024), the panel linear model (plm) package (Croissant and Millo, 2008), produced to handle longitudinal data

sophisticatedly, and the `clubSandwich` package (Pustejovsky, 2024), to cluster the standard errors, were used. The code is presented in Appendix 4.5.

Table 4.3

Variables included in the dataset.

Variable Name	Variable Description	Variable Responses
<i>regionIDFac</i>	A factor variable identifying the region of each local authority resides in, including an England identifier.	0 = “England”, 1 = “North East”, ..., 9 = “London”
<i>regionIDFacrefL</i>	A factor variable identifying the region of each local authority resides in, including an England identifier. The reference category is set to “London”.	0 = “England”, 1 = “North East”, ..., 9 = “London”
<i>laID</i>	A numerical variable with each unique number representing a specific local authority.	Ranging from 1 to 150.
<i>laIDFac</i>	A factor variable of <i>laID</i> with each unique number representing a specific local authority.	1 = “Sunderland”, ..., 150 = “Barking and Dagenham”
<i>timePointsPub</i>	A numerical variable representing each quarter where uptake was evaluated.	Ranging from 0 to 31.
<i>timePointsPubFac</i>	A factor variable of <i>timePointsPub</i> identifying each quarter where uptake was evaluated.	0 = “Jun 2016”, ..., 31 = “2024 Mar”
<i>timePoints</i>	A numerical variable representing each quarter where uptake has occurred, <i>timePointsPub</i> lagged by seven quarters.	Ranging from 0 to 31.
<i>timePointsFac</i>	A factor variable of <i>timePoints</i> identifying each quarter where uptake was administered, <i>timePointsPub</i> lagged by seven quarters.	0 = “2014 Mar”, ..., 31 = “2022 Jun”
<i>timeAnalysis</i>	A numerical variable representing each quarter where uptake has occurred, <i>timePointsPub</i> lagged by seven quarters. It is identical to <i>timePoints</i> . When <i>timePoints</i> is used to identify the panel structure, plm treats the main effect as a factor variable, this ensures it is numerical.	Ranging from 0 to 31.
<i>nChild</i>	A numerical variable stating the number of vaccination-eligible children in a given local authority at each time point, provided as standard in all COVER publications.	Ranging from 2 to 5,103.

<i>preb</i>	A proportion variable containing the information regarding the percentage of eligible children who received two doses of the DTaP/IPV (pre-school booster) vaccination before their fifth birthday in each 150 local authorities at 31 time points.	Ranging from 0.318 to 1.
<i>prebNChild</i>	A numerical variable stating the number of children vaccinated with the pre-school booster in a given local authority at each time point.	Ranging from 2 to 4,480.
<i>mmr</i>	A proportion variable containing the information regarding the percentage of eligible children who received two doses of the mmr vaccination before their fifth birthday in each 150 local authorities at 31 time points.	Ranging from 0.4430524 to 1.
<i>mmrNChild</i>	A numerical variable stating the number of children vaccinated with the two doses of the MMR vaccine in a given local authority at each time point.	Ranging from 2 to 4,480.
<i>imdRank</i>	A numerical variable representing the 2019 indices of multiple deprivation of average rank for a given local authority.	Ranging from 3,651.54 to 26,765.29.
<i>imdRAR</i>	A numerical variable representing the 2019 indices of multiple deprivation rank of average rank for a given local authority.	Ranging from 1 to 150.
<i>highDep20</i>	A factor variable that grouped local authorities into deprivation deciles using the <i>imdRAR</i> variable.	1 = “one of the 20% most deprived local authorities (Quintile 1)”, ..., 5 = “one of the 20% least deprived local authorities (Quintile 5)”
<i>highDep20ref3</i>	A factor variable that grouped local authorities into deprivation deciles using the <i>imdRAR</i> variable. The reference category is set to “Quintile 3”.	1 = “one of the 20% most deprived local authorities (Quintile 1)”, ..., 5 = “one of the 20% least deprived local authorities (Quintile 5)”
<i>lockdownLag</i>	Ordinal variable representing the piecewise term indicating the lagged effect of the first lockdown.	Ranges from 0 to 31.

<i>phaseOneVacLag</i>	Ordinal variable representing the piecewise term indicating the lagged effect of Phase 1 of COVID-19 vaccination rollout.	Ranges from 0 to 31.
<i>phaseTwoVac</i>	Ordinal variable representing the piecewise term indicating the occurrence of Phase 2 of COVID-19 vaccination rollout.	Ranges from 0 to 31.

4.4. Findings

4.4.1. Annual uptake descriptives

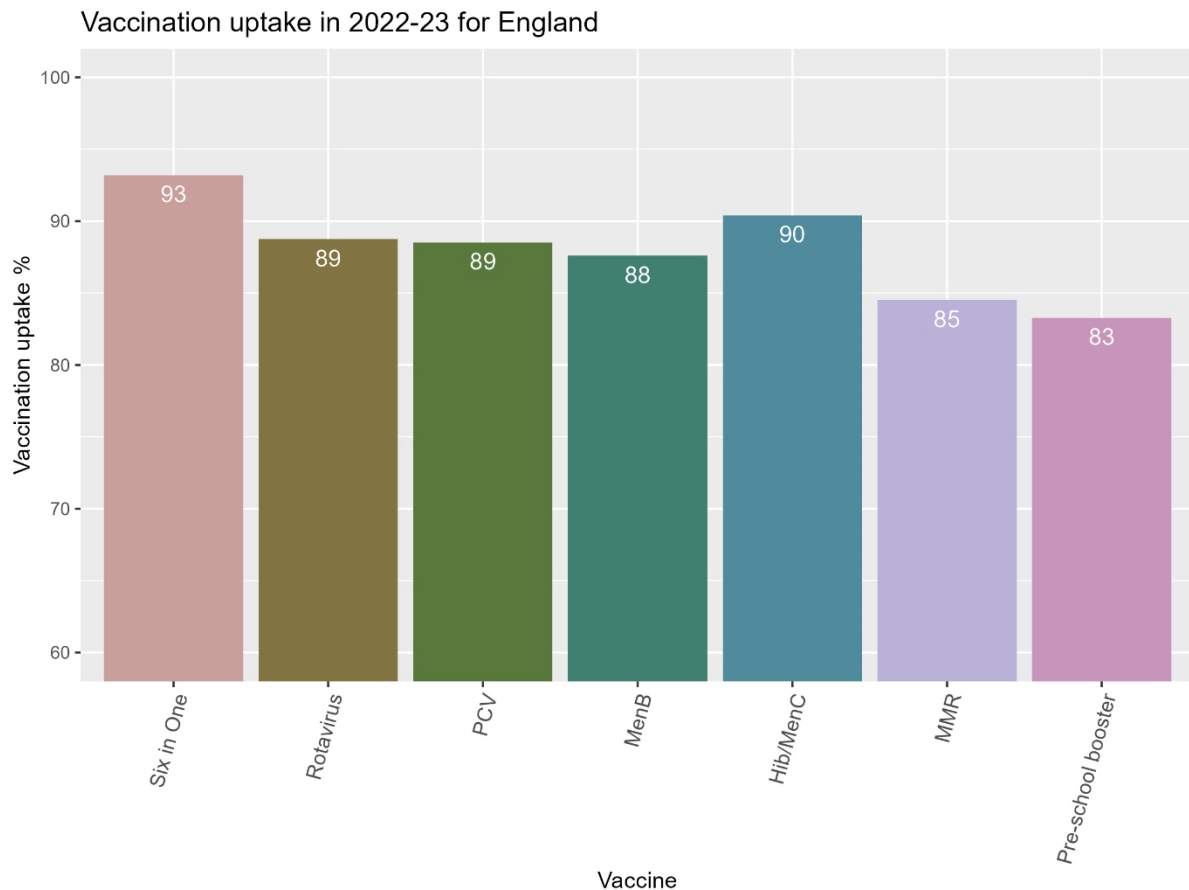
This section first provides the details of the exploratory analysis, which justifies the subsequent focus on the pre-school booster and the MMR vaccine. Then, the uptake of these vaccinations is probed further, both with and without the effect of deprivation. Following this, the results of the piecewise regressions exploring the effect of the lagged beginning of the first lockdown and vaccination rollout Phases 1 and 2 are presented. To conclude the main analysis, the role of regional differences in vaccination uptake according to deprivation and the effect of the three COVID-19 events is investigated. The results of some important robustness tests are discussed to ascertain the sensitivity of the analysis.

The most recent annual publication on childhood vaccination uptake (2022-23 financial year) was utilised for the exploratory investigation to provide an overview of uptake. Figure 4.2 illustrates the different levels of uptake for all vaccines administered before age five in England for this period, as recorded at 12 months, 24 months, and 5 years. For more information on the childhood vaccination schedule, including when uptake occurred and when it was evaluated, please refer to Section 4.2.1, *Vaccination uptake data*. The descriptive statistics for this component of the exploratory analysis are presented in Appendix 4.5.

As Figure 4.2 suggests, uptake is not consistent across all vaccines. Nationally, for 2022-23, none of the childhood vaccinations achieved the desired target of 95% required for herd immunity, with a population mean of 88.04% (standard deviation (SD) = 3.12%). However, the 6-in-1 vaccine, where three doses are administered before the age of one, outperformed all other childhood vaccines with an uptake of 93%, closely followed by one dose of Hib/MenC at 90%, the two doses of Rotavirus (89%) and PCV (89%), and three doses of MenB (88%). However, the two doses of MMR achieved only 85%, and the pre-school booster 83%, 10% less than the 6-in-1 vaccination. To contextualise these statistics, the 6-in-1 vaccine is used as an example: the total number of registered, eligible children for this vaccine was 680,892 nationally, and, of these children, 634,566 received this vaccine, meaning 46,326 did not.

Figure 4.2

A bar graph of vaccination uptake for the 2022-23 financial year for all vaccines administered before age five in England. To better visualise the nuances of uptake, the graph has been zoomed in, showing 60-100% on the y-axis.



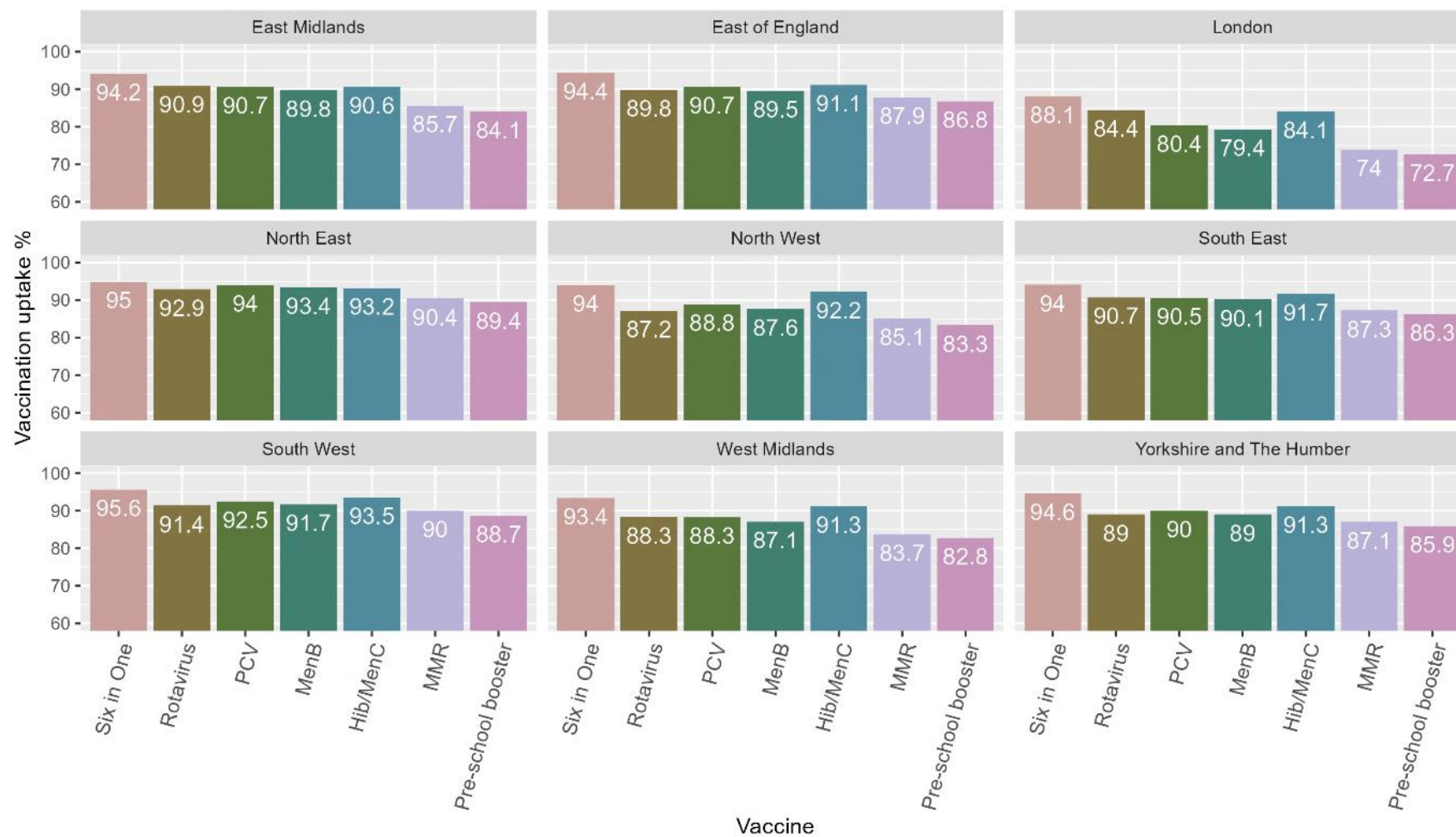
However, regions perform inconsistently when uptake is disaggregated, as presented in Figure 4.3. London (mean = 80.43%, SD = 5.23%) achieves the lowest uptake across all vaccines, with lows of 72.7% for the pre-school booster and highs of 88.1% for the 6-in-1 vaccine. On the other hand, the South East achieved the highest coverage for any vaccine across any region, with 95.6% uptake of the 6-in-1, but the North East achieved the highest mean uptake across all vaccines, mean = 92.6%, SD = 1.83%). The North East (mean = 92.6%, SD = 1.83%) and South West appear to have similar vaccine uptake levels, although the former slightly outperforms the latter for five of the seven vaccines; lower coverage is only present for Hib/MenC (93.2% = North East, 93.5% North West) and the 6-in-1 (95% = North East, 95.6% North West) vaccines.

Across all regions for each vaccine, the 6-in-1 had the highest average (mean = 93.7%, SD = 2.06%), and the MMR (mean = 85.67%, SD = 4.61%) and pre-school booster (mean = 84.44%, SD = 4.68%) had the two lowest. The standard deviation of the two lowest-averaging vaccines was more than twice that of the highest-averaging vaccine, demonstrating greater variability in uptake across regions.

This preliminary investigation aimed to select a smaller group of vaccines on which to focus the main analysis. There was an evident reduction in uptake for the two doses of MMR and the pre-school booster compared to the other five childhood vaccines. It also demonstrated that uptake for all vaccines is not consistent across regions. Additionally, Section 3.1.2, *Narrowing the scope*, suggested that the mixed methods study could explore whether there is lower vaccination uptake for advantaged socioeconomic groups. This inverse association is most evident for the MMR vaccine. Therefore, selecting the MMR vaccine and the pre-school booster for further analysis would permit this.

Figure 4.3

A stacked bar graph of vaccination uptake for the 2022-23 financial year for all vaccines administered before age five in England, reported by region. To better visualise the nuances of uptake, the graph has been zoomed in, showing 60-100% on the y-axis.

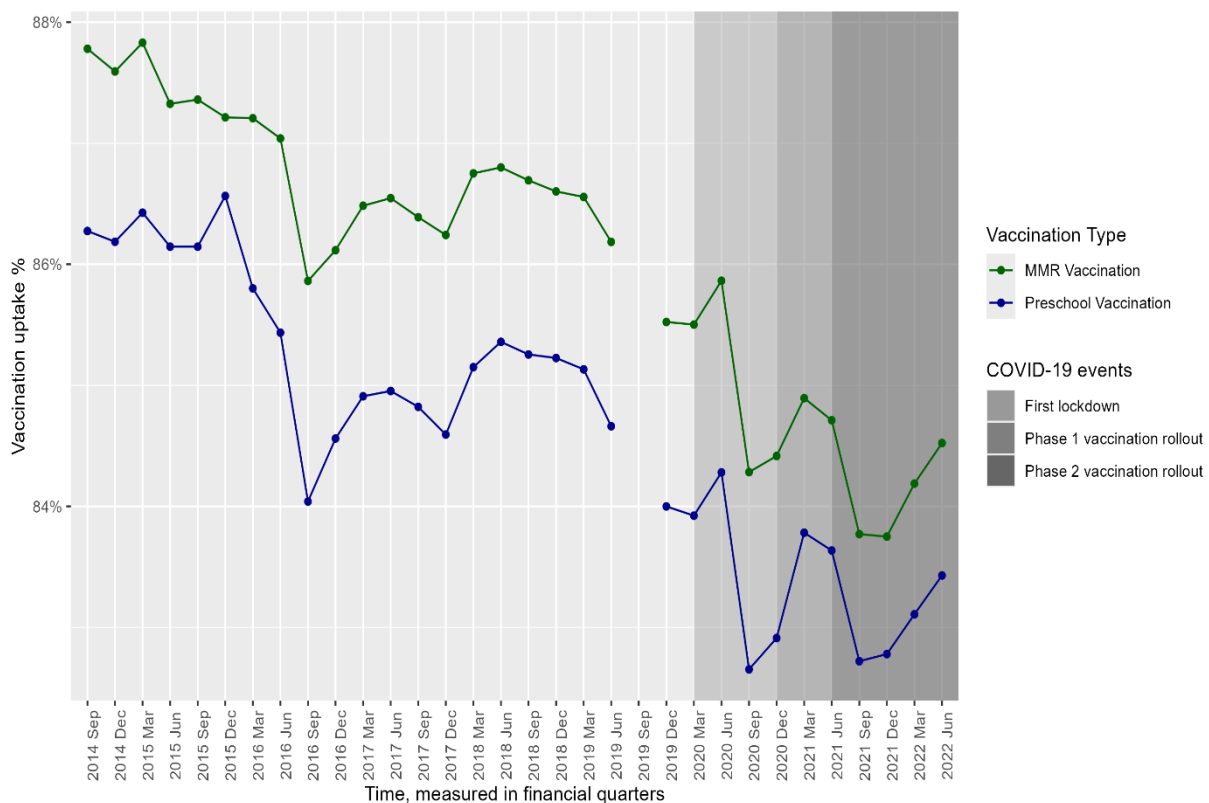


4.4.2. MMR vaccine and pre-school booster time trends

Regional and national data was first explored, followed by local authority data, to establish the general uptake trends for the pre-school booster and MMR vaccines across the study period: July – September 2014 to April – June 2022. The England averages for both vaccines are illustrated in Figure 4.4. Uptake for the two cumulative doses of the MMR vaccine was greater than that of the pre-school booster throughout the study period. However, they both follow similar patterns. There appears to be a steeper decline around the lagged beginning of the first lockdown.

Figure 4.4

England's average uptake of the pre-school booster and MMR vaccine across the study period (July – September 2014 to April – June 2022).



4.4.3. Pre-school booster uptake descriptives

Moreover, as detailed in Table 4.4 and illustrated in Figure 4.5, heterogeneity across regions was evident when uptake for the pre-school booster was disaggregated. A more detailed version of the descriptive statistics is presented in Appendix 4.6. The 95% target

for the pre-school booster was not achieved for the entire study period. The England average was 86.25% (Min = 84.17% in September 2021, max = 87.95% in March 2015).

The North East was the only region that achieved an average of 90% pre-school booster uptake (mean = 90.16%) across the study period. This region also attained the highest level of uptake of any quarter and region, with 93.03% in December 2014. Seven regions averaged above 85%, aside from London, with a mean of 72.91%. The highest level of uptake London accomplished was 76.67% in December 2017, and the lowest was in September 2020, with 68.73%.

Table 4.4

Summary statistics of pre-school booster uptake across the study period from July – September 2014 to April – June 2022 disaggregated by region.

Pre-school Booster	Average	Min	Max	Range
<i>North East</i>	90.13%	87.81%	93.03%	5.21%
<i>Yorkshire and the Humber</i>	89.12%	85.87%	91.31%	5.43%
<i>North West</i>	87.32%	82.91%	90.57%	7.66%
<i>East Midlands</i>	86.57%	83.55%	88.68%	5.13%
<i>West Midlands</i>	86.88%	83.81%	90.81%	7.00%
<i>South West</i>	89.93%	87.60%	91.47%	3.87%
<i>South East</i>	86.28%	83.47%	89.15%	5.68%
<i>East of England</i>	87.11%	85.12%	89.31%	4.19%
<i>London</i>	72.91%	68.73%	76.67%	7.93%
England Total	86.25%	84.17%	87.95%	3.78%

Figure 4.5 more clearly illustrates the differences across regions and the lower uptake levels for London. The other eight regions, including the England average, are clustered in the top portion of the graph. London also appears to vary more than other regions, as demonstrated in Table 4.4, which identifies the range in average uptake for London across the study period as 7.93%. The range for the South West was only 3.87%, demonstrating less fluctuation.

Moreover, Table 4.5 and Figure 4.6 show the difference in uptake for the pre-school booster across deprivation quintiles. The uptake amongst the “Most deprived 20% (Quintile 1)” of local authorities has one of the largest decreases across the study period, with a range of 9.82%. Meanwhile, the “Least deprived 20% (Quintile 5)” range was 2.93%, demonstrating less variation. Local authorities classified as the “Least deprived

20% (Quintile 5)” averaged 87.23% uptake, the highest of all quintiles. The pre-school booster uptake for each deprivation quintile is shown in Appendix 4.7.

Table 4.5

Summary statistics of pre-school booster uptake across the study period from July – September 2014 to April – June 2022 disaggregated by deprivation quintile.

Pre-school Booster	Average	Min	Max	Range
<i>Least deprived 20% (Quintile 5)</i>	87.23%	85.98%	88.90%	2.93%
<i>Quintile 4</i>	85.81%	84.15%	88.05%	3.89%
<i>Quintile 3</i>	82.91%	81.03%	85.35%	4.33%
<i>Quintile 2</i>	85.11%	82.69%	87.93%	5.24%
<i>Most deprived 20% (Quintile 1)</i>	82.30%	77.58%	87.40%	9.82%

At the beginning of the study period, uptake for each quintile was more clustered, and the spread gradually widened. Evidently, pre-school booster uptake was declining before the COVID-19 pandemic. What was unclear is whether the pandemic had a further significant impact, which will be explored in Section 4.4.5, *Piecewise regressions*.

Figure 4.5

National and regional uptake of the pre-school vaccine across the study period from July – September 2014 to April – June 2022 (2019 Sep is missing data).

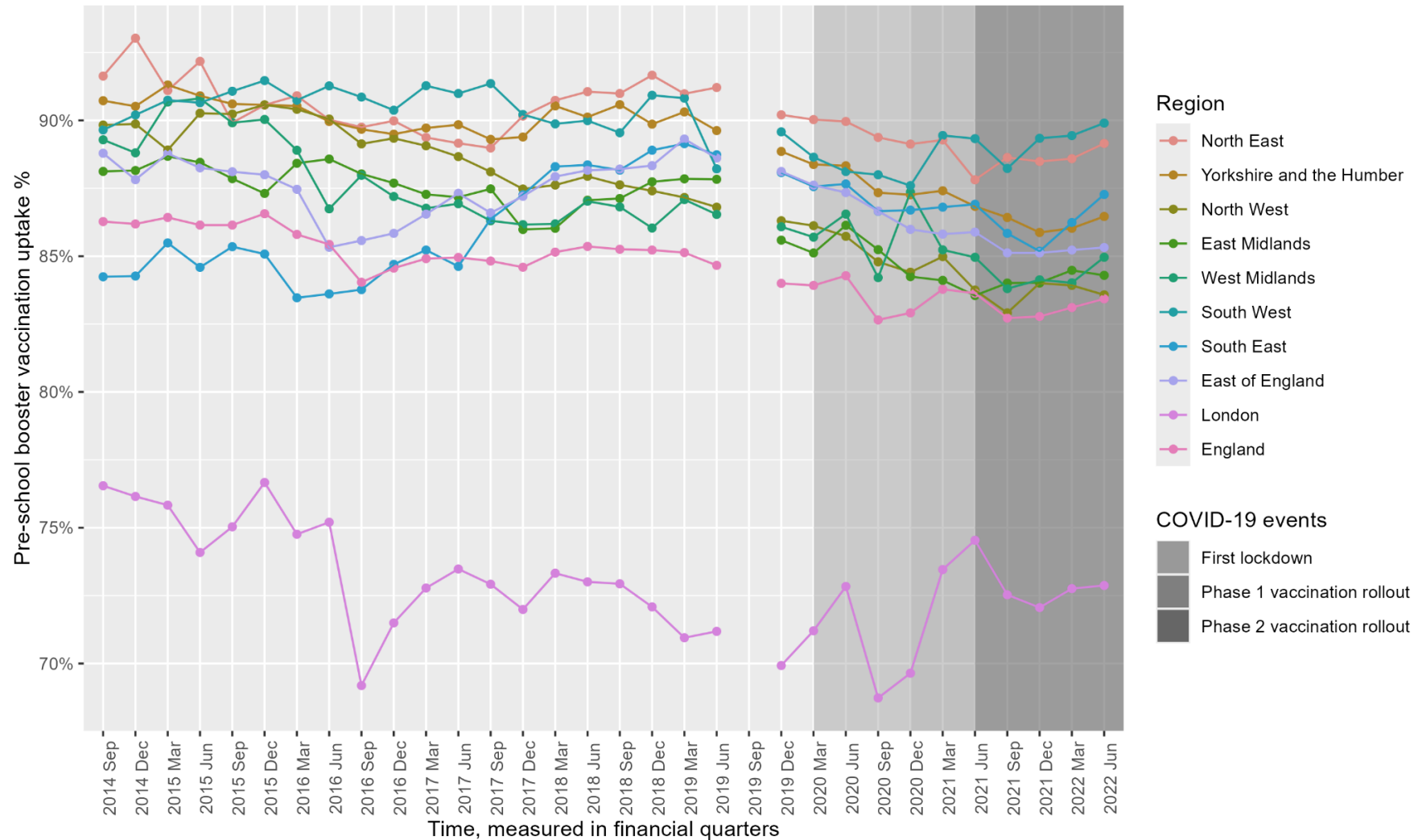
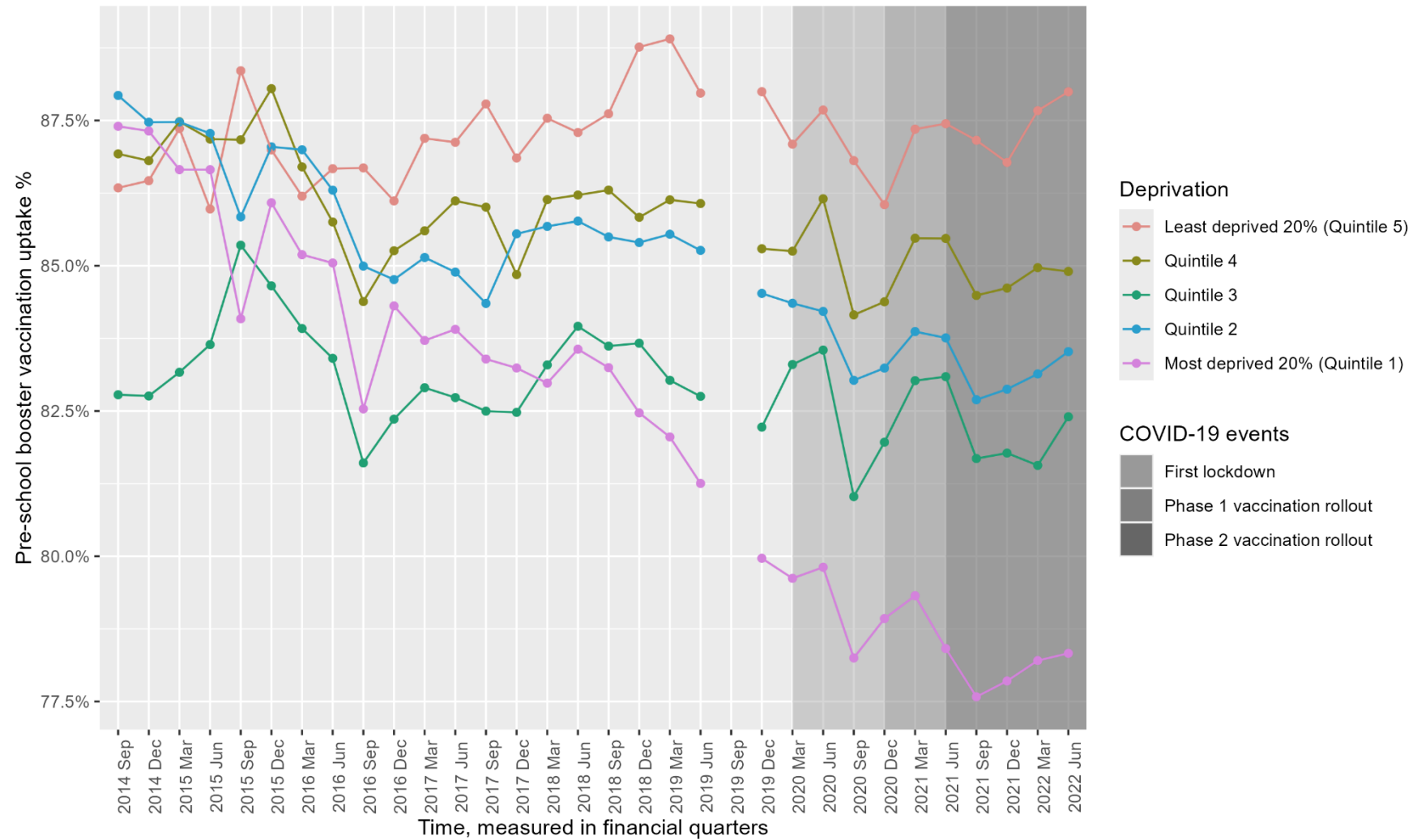


Figure 4.6

Pre-school booster vaccination uptake across the study period from July – September 2014 to April – June 2022 across deprivation quintiles (2019 Sep is missing data).



4.4.4. MMR uptake descriptives

MMR vaccine uptake followed a similar trend to the pre-school booster. The 95% uptake target was not achieved during the study period, with England's average fluctuating between 85.23% and 89.05%, demonstrating an overall decline (see Table 4.6 and Figure 4.7). The North East and South West averaged above 90% uptake during the study period, with the former achieving the highest proportion of uptake of any quarter, with 93.6% of the target population vaccinated in December 2014. Six of the remaining seven regions averaged above 87%, aside from London, which averaged 74.88% uptake, with lows of 71.11% in September 2020. There was a greater fluctuation in uptake across the study period in London for the MMR vaccine than was identified for the preschool booster, with ranges of 8.66% and 7.93%, respectively. A more detailed version of the descriptive statistics is available in Appendix 4.8.

Table 4.6

Summary statistics of MMR vaccine uptake across the study period from July – September 2014 to April – June 2022 disaggregated by deprivation quintile.

MMR Vaccine	Average	Min	Max	Range
<i>North East</i>	91.25%	89.27%	93.15%	3.88%
<i>Yorkshire and the Humber</i>	89.88%	86.77%	91.37%	4.60%
<i>North West</i>	88.48%	84.95%	90.90%	5.94%
<i>East Midlands</i>	87.68%	84.89%	89.60%	4.72%
<i>West Midlands</i>	87.91%	84.88%	92.04%	7.16%
<i>South West</i>	91.47%	89.51%	92.62%	3.11%
<i>South East</i>	88.02%	86.10%	90.14%	4.04%
<i>East of England</i>	88.33%	85.99%	90.18%	4.19%
<i>London</i>	74.88%	71.11%	79.77%	8.66%
England Total	87.55%	85.23%	89.05%	3.82%

Based on a visual assessment of Figure 4.7, uptake for MMR appeared to have a more evident decline around the lagged beginning of the first lockdown. However, the inclusion of London in these graphs hinders the ability to identify the nuances across all regions because of their lower uptake levels. Thus, in Section 4.4.7, *Exploring the effects of region*, London is removed from the analysis to address this issue as it is present for both the pre-school booster and MMR vaccine.

Moreover, Figure 4.8 and Table 4.7 show the difference in uptake across deprivation quintiles for the MMR vaccination. They demonstrate a decline across most quintiles, as did the pre-school booster. The “Least deprived 20% (Quintile 5)” averaged 5.08% higher uptake than the “Most deprived 20% (Quintile 1)”. However, “Quintile 3” averaged a similar level of uptake (83.87%) as the “Most deprived 20% (Quintile 1)” (83.69%), yet “Quintile 2” had a greater average (86.77%). MMR vaccine uptake for each deprivation quintile is presented in Appendix 4.9.

Table 4.7

Summary statistics of MMR vaccine uptake across the study period from July – September 2014 to April – June 2022 disaggregated by deprivation quintile.

MMR Vaccine	Average	Min	Max	Range
<i>Least deprived 20% (Quintile 5)</i>	88.76%	86.83%	90.42%	3.59%
<i>Quintile 4</i>	87.22%	85.43%	88.99%	3.56%
<i>Quintile 3</i>	83.87%	82.30%	85.48%	3.18%
<i>Quintile 2</i>	86.77%	83.76%	88.92%	5.16%
<i>Most deprived 20% (Quintile 1)</i>	83.69%	79.04%	88.42%	9.38%

As Figure 4.8 illustrates, uptake amongst the “Most deprived 20% (Quintile 1)” of local authorities has seen one of the most significant decreases across the study period, with a range of 9.38% (see Table 4.7). The “Least deprived 20% (Quintile 5)” range was 3.59%, demonstrating less variation. Local authorities in the “Least deprived 20% (Quintile 5)” averaged 88.76%, the highest of all quintiles.

Figure 4.7

National and regional uptake of the MMR vaccine across the study period from July – September 2014 to April – June 2022 (2019 Sep is missing data).

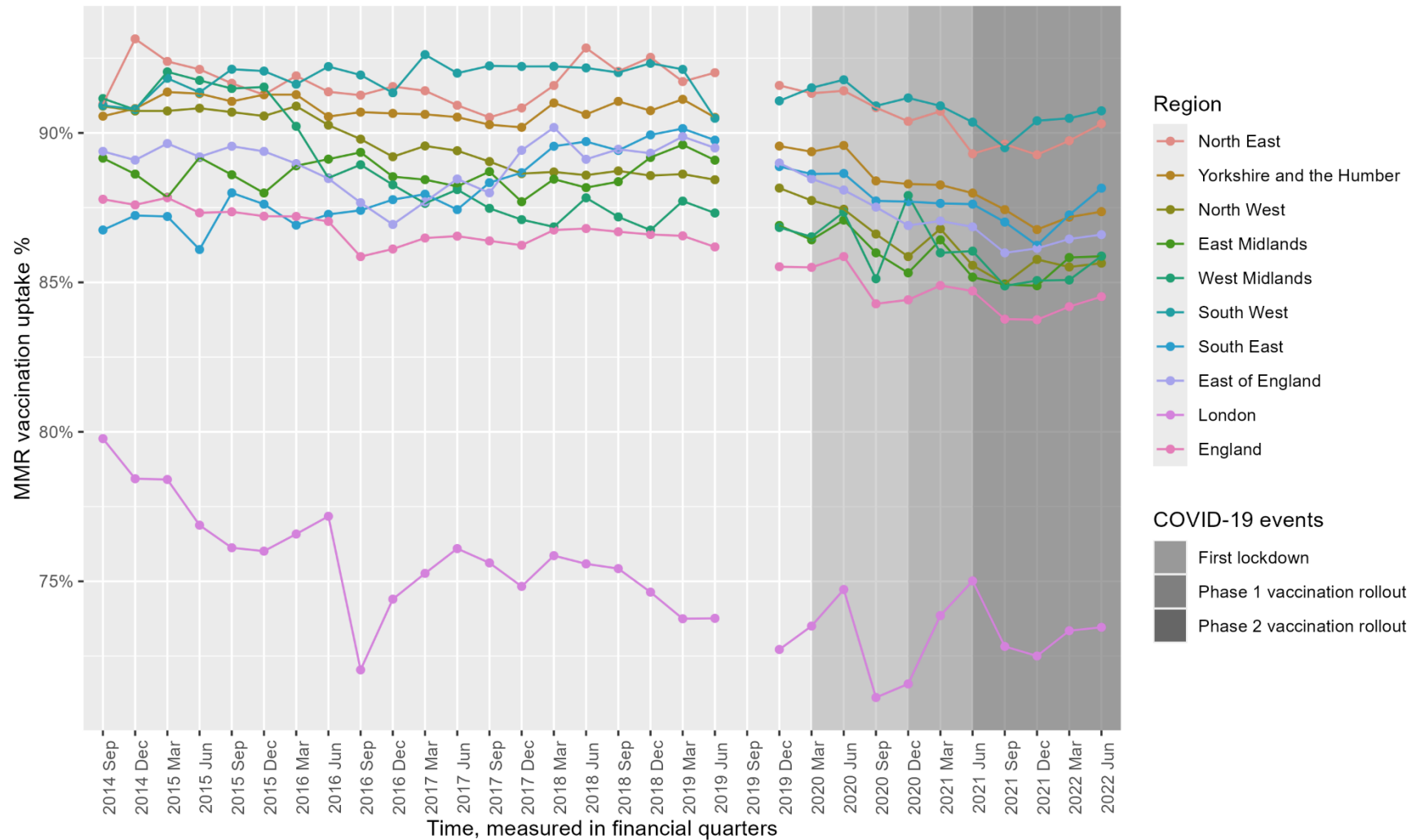
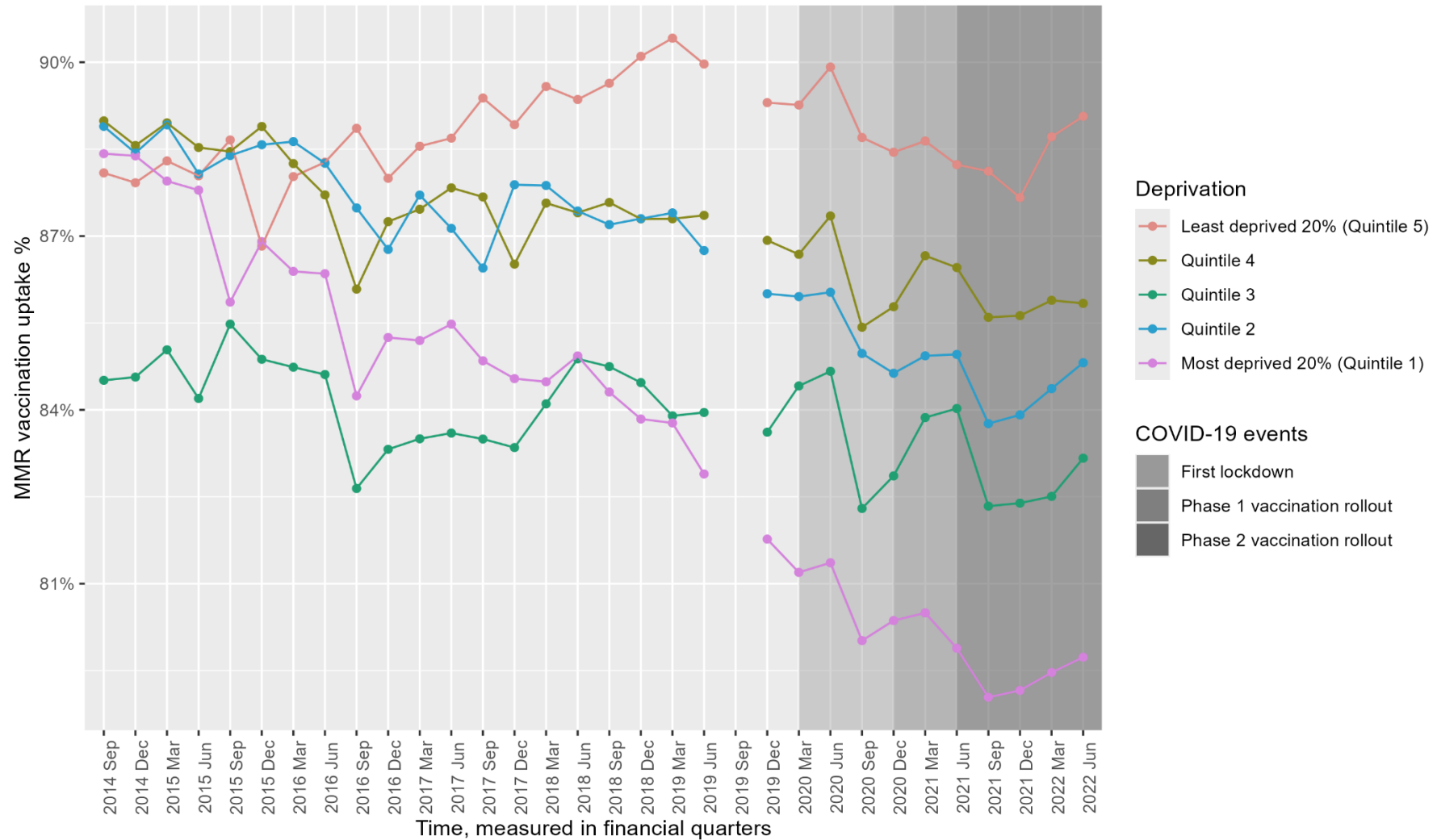


Figure 4.8

Measles, mumps, and rubella vaccination uptake across the study period from July – September 2014 to April – June 2022 across deprivation quintile (2019 Sep is missing data).



4.4.5. Findings: piecewise regressions

The exploratory analysis demonstrated that uptake has been declining, but the rate of this decline appears inconsistent across regions and deprivation quintiles. Whether COVID-19 has exacerbated this and further contributed to increasing socioeconomic inequalities is unclear.

The results of the segmented regression for the pre-school booster are detailed in Table 4.8, demonstrating a clear decline in uptake across the entire study period, decreasing by 0.101% (95% CI -0.119% to -0.083%) per quarter. This means that, on average, there was a 0.101% decrease in pre-school booster uptake per quarter. Considering these effects are cumulative, in one year, this could result in a 0.404% decrease.

There was no overall effect of lockdown on uptake, but there were interaction effects for the two most deprived quintiles. For “Quintile 2”, this decrease was 0.054% (95% CI -0.097% to -0.011%) per quarter, and for the “Most deprived 20% (Quintile 5)”, 0.138% (95% CI -0.189% to -0.087%), compared to “Quintile 3”. No additional main effects of Phase 1 or Phase 2 COVID-19 vaccination rollout were identified, and no statistically significant interaction effects for deprivation quintiles for these events.

From these results, it can be inferred that socioeconomic inequalities in pre-school booster vaccination uptake may have widened during the pandemic. This was suggested by a significant decline for the most deprived quintile and no evidence of a decline for quintiles two, four and five. However, the Adjusted R^2 value is 12.8%, suggesting that the selected breakpoints and their interaction with deprivation account for a small proportion of the variation in uptake.

Table 4.8

The results of a fixed effects linear piecewise regression analysing pre-school booster vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events.

Piecewise regression of pre-school booster vaccine uptake				
	Adjusted R ² = 12.8%	estimate	95% CI	
Time		-0.101%	-0.119%	-0.083% ***
Lockdown (ref. Quintile 3)		0.004%	-0.028%	0.036%
<i>Lockdown: Least deprived 20% (Quintile 5)</i>		0.024%	-0.020%	0.067%
<i>Lockdown: Quintile 4</i>		-0.007%	-0.050%	0.036%
<i>Lockdown: Quintile 2</i>		-0.054%	-0.097%	-0.011% *
<i>Lockdown: Most deprived 20% (Quintile 1)</i>		-0.157%	-0.200%	-0.114% ***
Phase 1 Vaccination Rollout (ref. Quintile 3)		0.041%	-0.013%	0.095%
<i>Phase 1: Least deprived 20% (Quintile 5)</i>		-0.003%	-0.080%	0.074%
<i>Phase 1: Quintile 4</i>		-0.003%	-0.080%	0.073%
<i>Phase 1: Quintile 2</i>		-0.016%	-0.092%	0.061%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>		-0.007%	-0.084%	0.069%
Phase 2 Vaccination Rollout (ref. Quintile 3)		-0.033%	-0.082%	0.017%
<i>Phase 2: Least deprived 20% (Quintile 5)</i>		0.024%	-0.046%	0.095%
<i>Phase 2: Quintile 4</i>		0.004%	-0.066%	0.074%
<i>Phase 2: Quintile 2</i>		0.019%	-0.051%	0.089%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>		0.007%	-0.063%	0.077%
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$				
Control variables: Number of vaccine-eligible children in a local authority each quarter.				

The results of the segmented regression for the MMR vaccine are presented in Table 4.9. As for the pre-school booster, the MMR vaccine experienced an overall decline in uptake across the study period, with an average decrease of 0.089% (95% CI -0.103% to -0.075%) per quarter, including no main effect of the first lockdown. Also identified were significant lockdown interaction effects, with an average 0.061% decrease (95% CI -0.097% to -0.026%) per quarter for “Quintile 2”, and 0.152% decrease (95% CI -0.188% to -0.094%) for the “Least deprived 20% (Quintile 5)”, compared to “Quintile 3”. Evidence of a positive lockdown interaction effect for the “Least deprived 20% (Quintile 5)” was also identified, with an average increase of 0.045% (95% CI 0.009% to 0.08%) per quarter compared to “Quintile 3”. No additional main effects of Phase 1 or Phase 2 COVID-19 vaccination rollout were identified, and no statistically significant changes for specific deprivation quintiles for these events.

There is evidence for widening socioeconomic inequalities in MMR vaccination, with an increase in uptake for local authorities defined as the “Least deprived 20% (Quintile 5)” and a decrease for local authorities in the two most deprived quintiles.

Moreover, the adjusted R^2 value for the MMR model was 19.48%, suggesting that the selected breakpoints and their interaction with deprivation explain a greater proportion of variation in uptake than for the pre-school booster (Adjusted R^2 = 12.8%). However, this figure is still relatively low, indicating that there is still a significant proportion of variation not accounted for by either of the models.

Table 4.9

The results of a fixed effects linear piecewise regression analysing MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events.

Piecewise regression of MMR vaccine uptake				
	Adjusted R^2 = 19.48%	estimate	95% CI	
Time		-0.089%	-0.103%	-0.075% ***
Lockdown (ref. Quintile 3)		0.002%	-0.024%	0.029%
<i>Lockdown: Least deprived 20% (Quintile 5)</i>		0.045%	0.009%	0.080% *
<i>Lockdown: Quintile 4</i>		-0.021%	-0.057%	0.014%
<i>Lockdown: Quintile 2</i>		-0.061%	-0.097%	-0.026% **
<i>Lockdown: Most deprived 20% (Quintile 1)</i>		-0.152%	-0.188%	-0.117% ***
Phase 1 Vaccination Rollout (ref. Quintile 3)		0.031%	-0.013%	0.075%
<i>Phase 1: Least deprived 20% (Quintile 5)</i>		-0.024%	-0.087%	0.039%
<i>Phase 1: Quintile 4</i>		0.003%	-0.060%	0.065%
<i>Phase 1: Quintile 2</i>		-0.030%	-0.093%	0.032%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>		-0.014%	-0.077%	0.049%
Phase 2 Vaccination Rollout (ref. Quintile 3)		-0.034%	-0.074%	0.006%
<i>Phase 2: Least deprived 20% (Quintile 5)</i>		0.009%	-0.048%	0.067%
<i>Phase 2: Quintile 4</i>		0.002%	-0.056%	0.059%
<i>Phase 2: Quintile 2</i>		0.026%	-0.031%	0.084%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>		0.016%	-0.041%	0.073%

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Control variables: Number of vaccine-eligible children in a local authority each quarter.

Diagnostic plots for both models can be viewed in Appendices 4.10, 4.11, 4.12, 4.13, 4.14 and 4.15. They indicate a violation of the normality assumption and heterogeneity. Clustering of robust standard errors was employed to minimise the impact of heteroskedasticity and autocorrelation. This could be due to outliers in the data,

although the diagnostics did not demonstrate a high Cook's D, indicating low levels of influence (see Appendix 4.12 and 4.15).

For these models, local authorities in London were included despite consistently experiencing lower uptake levels for both vaccines, which could potentially skew the findings. Including local authorities in London could decrease the average uptake, as evident in Figures 4.5 and 4.7. To address this issue, the analysis was repeated, and local authorities in London were removed. The results of these analyses are presented in the following section.

4.4.6. Excluding London

The plots from the exploratory analyses were reproduced, excluding local authorities in London, and are presented in Figures 4.9 and 4.10 for the pre-school booster and MMR vaccine, respectively.

For the pre-school booster, Figure 4.9 demonstrates a similar pattern to Figure 4.6, which includes local authorities in London. Namely, the “Most deprived 20% (Quintile 1)” underperformed compared to the rest of the quintiles, and there appears to be a faster rate of decline around COVID-19 for this group. However, the piecewise regression results differ slightly when local authorities in London are removed. Table 4.10 presents the results for the pre-school booster. The diagnostic plots can be viewed in Appendices 4.16, 4.17, and 4.18. They indicate a violation of the normality assumption and heterogeneity. However, the Cook's D figures are reduced in this context compared to when London was included.

The analysis suggests an overall decline in uptake across the study period by an average of 0.055% (95% CI -0.072% to -0.038%) per quarter. Unlike the regression that included local authorities in London, the main effect of the first lockdown contributed to a 0.042% (95% CI -0.074% to -0.011%) decline in uptake per quarter and an increase in uptake for the “Least deprived 20% (Quintile 5)” by an average of 0.053% (95% CI 0.011% to 0.095%) per quarter when compared to local authorities in “Quintile 3”. However, there is no evidence to suggest a decline for “Quintile 2” when London is removed, but a similar decline in uptake amongst the “Most deprived 20% (Quintile 1)” by an average of 0.112%

(95% CI -0.155% to -0.07%) per quarter when compared to local authorities in “Quintile 3”. No additional main effect of Phase 1 or Phase 2 COVID-19 vaccination rollout was identified, and no statistically significant changes for specific deprivation quintiles for these events.

Table 4.10

The results of a fixed effects linear piecewise regression analysing pre-school booster uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events, excluding local authorities in London.

Piecewise regression of pre-school booster uptake, excluding London				
	Adjusted R ² = 15.92%	estimate	95% CI	
Time		-0.055%	-0.072%	-0.038% ***
Lockdown (ref. Quintile 3)		-0.042%	-0.074%	-0.011% **
<i>Lockdown: Least deprived 20% (Quintile 5)</i>		0.053%	0.011%	0.095% *
<i>Lockdown: Quintile 4</i>		0.036%	-0.007%	0.078%
<i>Lockdown: Quintile 2</i>		-0.006%	-0.048%	0.036%
<i>Lockdown: Most deprived 20% (Quintile 1)</i>		-0.112%	-0.155%	-0.070% ***
Phase 1 Vaccination Rollout (ref. Quintile 3)		0.018%	-0.036%	0.071%
<i>Phase 1: Least deprived 20% (Quintile 5)</i>		-0.009%	-0.084%	0.066%
<i>Phase 1: Quintile 4</i>		-0.013%	-0.088%	0.063%
<i>Phase 1: Quintile 2</i>		-0.025%	-0.100%	0.049%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>		-0.014%	-0.090%	0.061%
Phase 2 Vaccination Rollout (ref. Quintile 3)		-0.027%	-0.075%	0.022%
<i>Phase 2: Least deprived 20% (Quintile 5)</i>		0.028%	-0.041%	0.096%
<i>Phase 2: Quintile 4</i>		0.000%	-0.069%	0.070%
<i>Phase 2: Quintile 2</i>		0.010%	-0.058%	0.078%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>		-0.007%	-0.076%	0.062%
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$				
Control variables: Number of vaccine-eligible children in a local authority each quarter.				

However, the adjusted R² value for the pre-school booster piecewise regression, including local authorities in London, was 15.92%; for the same model without London, this was 12.8%. The increase in the adjusted R² when London is removed suggests that the selected parameters have greater explanatory capabilities than when included. Thus, London could be a more complex case study which does not necessarily conform to common trends.

Similar to the pre-school booster, trends in uptake for the MMR vaccine appeared to follow a similar pattern when London was removed, as illustrated by Figure 4.10. The

“Most deprived 20% (Quintile 1)” of local authorities underperformed compared to the other four quintiles, and there appeared to be an increase in the rate of decline around COVID-19 for this group. The results of the segmented regression for the MMR vaccine excluding local authorities in London are presented in Table 4.11. The diagnostic plots can be viewed in Appendices 4.19, 4.20, and 4.21. They indicate a violation of the normality assumption and heterogeneity. However, the Cook’s D figures are reduced in this context compared to when London was included.

Similar to the piecewise regression of pre-school booster uptake without London, there was a significant overall effect of time, with MMR coverage decreasing by an average of 0.041% (95% CI -0.066% to -0.016%) per quarter. The main effects of the first lockdown were identified, with an overall decrease of 0.041% (95% CI -0.066% to -0.016%) in MMR uptake per quarter.

There was evidence of an average increase in uptake of 0.082% (95% CI 0.049% to 0.115%) per quarter for the “Least deprived 20% (Quintile 5)” when compared to “Quintile 3”, and a decrease of 0.103% (95% CI -0.136% to -0.069%) for the “Most deprived 20% (Quintile 1)”, both of which were evident in the MMR models including London. No additional main effect of Phase 1 or Phase 2 COVID-19 vaccination rollout was identified, and no statistically significant changes for specific deprivation quintiles for these events.

Table 4.11

The results of a fixed effects linear piecewise regression analysing MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events, excluding local authorities in London.

Piecewise regression of MMR vaccine uptake, excluding London				
Adjusted R ² = 22.65%	estimate	95% CI		
Time	-0.050%	-0.063%	-0.036%	***
Lockdown (ref. Quintile 3)	-0.041%	-0.066%	-0.016%	**
<i>Lockdown: Least deprived 20% (Quintile 5)</i>	0.082%	0.049%	0.115%	***
<i>Lockdown: Quintile 4</i>	0.022%	-0.012%	0.056%	
<i>Lockdown: Quintile 2</i>	-0.011%	-0.044%	0.022%	
<i>Lockdown: Most deprived 20% (Quintile 1)</i>	-0.103%	-0.136%	-0.069%	***
Phase 1 Vaccination Rollout (ref. Quintile 3)	0.020%	-0.022%	0.062%	
<i>Phase 1: Least deprived 20% (Quintile 5)</i>	-0.033%	-0.092%	0.026%	
<i>Phase 1: Quintile 4</i>	-0.001%	-0.061%	0.059%	
<i>Phase 1: Quintile 2</i>	-0.040%	-0.099%	0.019%	
<i>Phase 1: Most deprived 20% (Quintile 1)</i>	-0.018%	-0.077%	0.042%	

Phase 2 Vaccination Rollout (ref. Quintile 3)	-0.031%	-0.069%	0.008%
<i>Phase 2: Least deprived 20% (Quintile 5)</i>	0.009%	-0.045%	0.063%
<i>Phase 2: Quintile 4</i>	-0.009%	-0.063%	0.046%
<i>Phase 2: Quintile 2</i>	0.022%	-0.032%	0.076%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>	0.001%	-0.054%	0.055%

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$
Control variables: Number of vaccine-eligible children in a local authority each quarter.

The segmented regression model exploring MMR vaccine uptake excluding London had an adjusted R^2 value of 22.65%, whereas the same model including London, was only 19.48%. This is a similar outcome in the context of the pre-school booster, meaning the selected parameters have more explanatory capabilities when local authorities in London are removed.

In summary, whilst the regressions perform better without London, they are still somewhat weak models overall. However, there are notable differences in this context: (1) for both the pre-school booster and MMR vaccine, the main effects of the first lockdown are evident; (2) arguably, there is more clear evidence of socioeconomic inequalities associated with the first lockdown when London local authorities are excluded from the analysis, suggested by a clear increase in uptake for both vaccines for the “Least deprived 20% (Quintile 5)”, and a decrease for the “Most deprived 20% (Quintile 1)”.

Figure 4.9

Pre-school booster vaccination uptake across the study period from July – September 2014 to April – June 2022 across deprivation quintiles, excluding local authorities in London (2019 Sep is missing data).

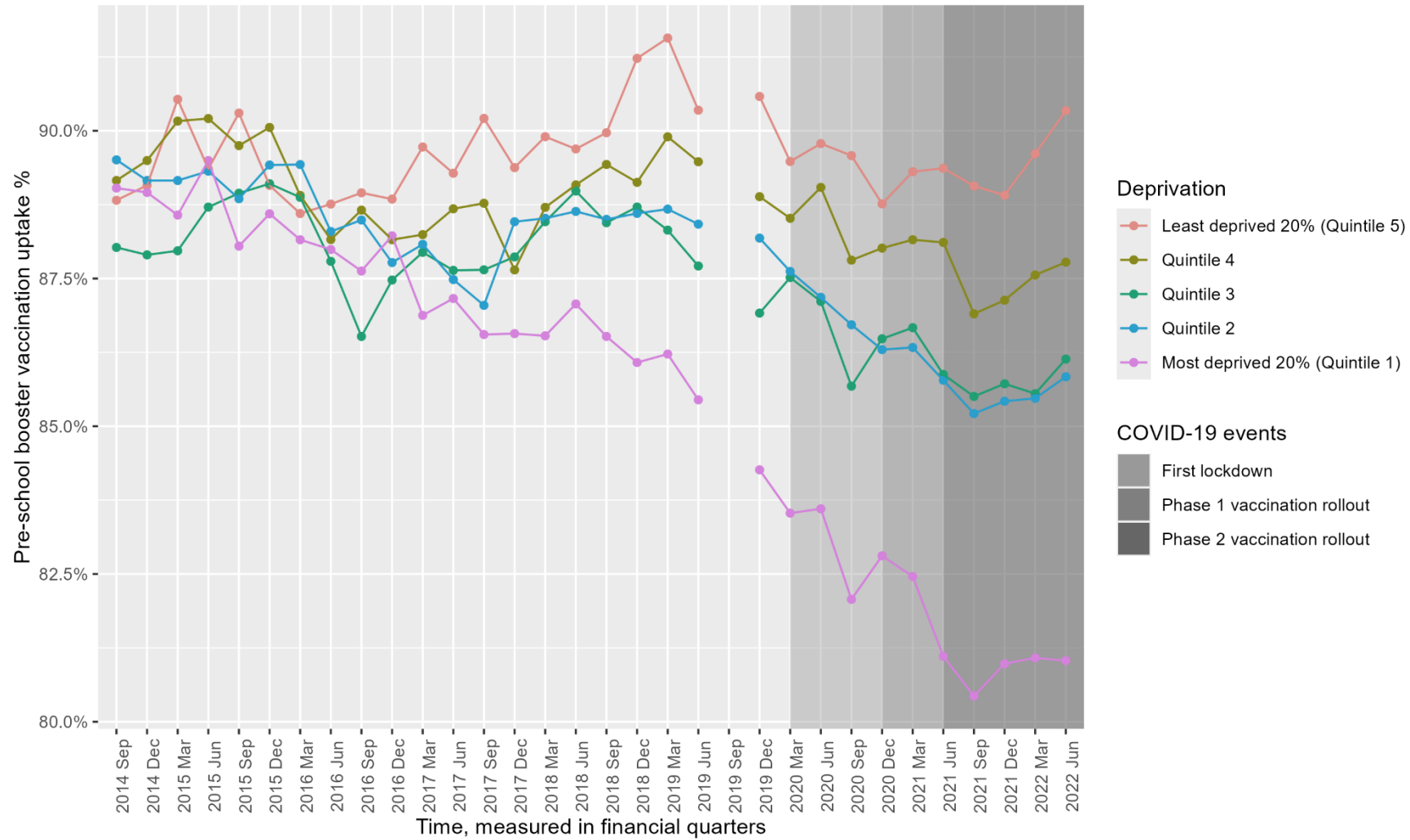
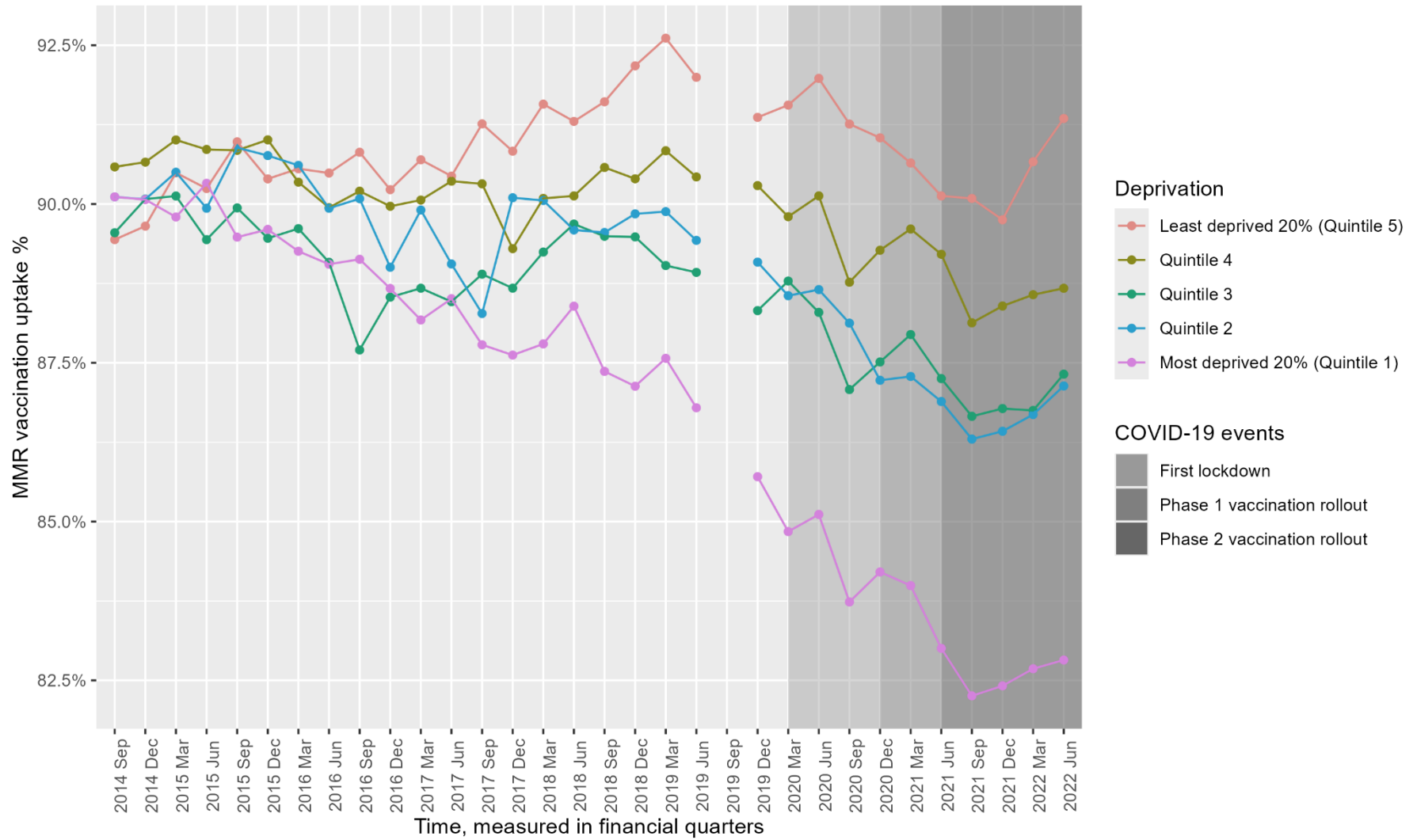


Figure 4.10

MMR vaccination uptake across the study period from July – September 2014 to April – June 2022 across deprivation quintiles, excluding local authorities in London (2019 Sep is missing data).



4.4.7. Exploring the effects of region

The interaction between region, deprivation, and COVID-19 is now explored. The results table for both the pre-school booster and MMR vaccine is provided in Appendix 4.23; the reference categories for these models were “Quintile 3” and London. Visual representations of the regressions are presented in Figure 4.11 (pre-school booster) and Figure 4.12 (MMR vaccine). An important fact to note is the high prevalence of missing data for this analysis due to the lack of local authorities classified as each of the deprivation quintiles for all regions. For example, when using the IMD rank of average rank, the North East has no local authorities classified as “Least deprived 20% (Quintile 5)”, meaning estimates and confidence intervals cannot be calculated.

Evidence supports a main lockdown interaction effect on pre-school booster uptake for Yorkshire and the Humber and the South West. For Yorkshire and the Humber, this was an average decline of 0.216% (95% CI -0.318% to -0.114%), East Midlands, 0.199% (95% CI -0.374 to -0.025%), and for the South West, an increase of 0.113% (95% CI 0.008% to 0.218%) per quarter compared to London.

When exploring the interaction between lockdown, region, and deprivation, local authorities in the North East, “Quintile 2” experienced an average increase in pre-school booster uptake of 0.208% (95% CI 0.061% to 0.355%) per quarter compared to “Quintile 3” and London. Lockdown effects were also identified for this region and the “Most deprived 20% (Quintile 1)” local authorities, with a similar increase of 0.316% (95% CI 0.171% to 0.461%).

For “Least deprived 20% (Quintile 5)”, an average increase of 0.284% (95% CI 0.127% to 0.441%) per quarter for Yorkshire and the Humber was found, as for “Quintile 2”, a 0.321% increase (95% CI 0.178% to 0.463%), and “Most deprived 20% (Quintile 1)”, a 0.332% increase (95% CI -0.18% to 0.484%).

In the context of the North West for local authorities classified as “Quintile 4”, an average increase in uptake of 0.205% (95% CI 0.057% to 0.353%) per quarter compared to London and “Quintile 3”. This effect was also evident for “Quintile 2”, with an average increase of 0.198% (95% CI 0.055% to 0.34%). For the East Midlands, “Least deprived 20% (Quintile 5)”, there was a 0.33% decrease (95% CI 0.108% to 0.552%).

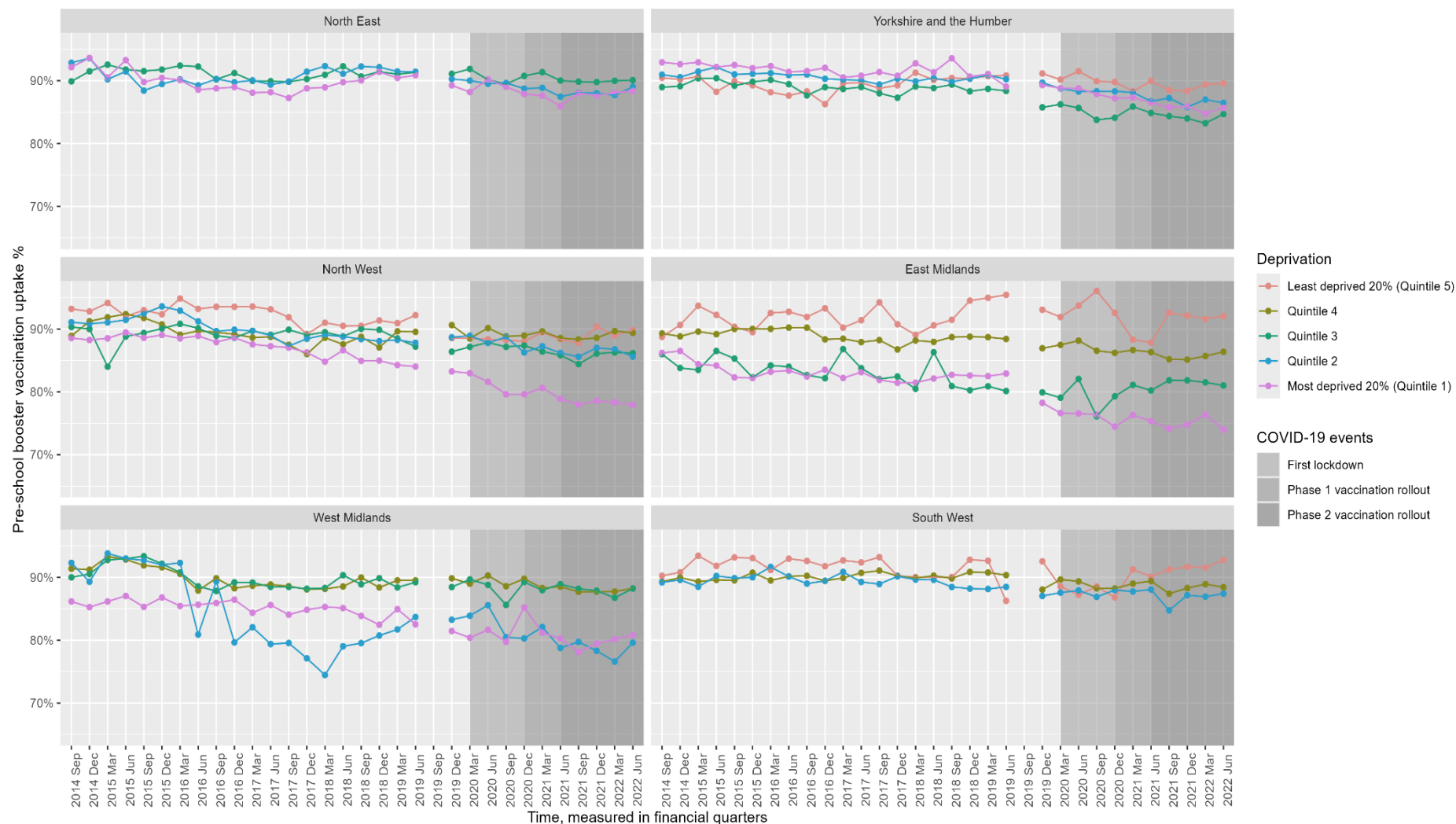
Evidence suggests a positive lockdown effect for “Quintile 4” local authorities in the West Midlands, by an average increase of 0.211% (95% CI 0.063% to 0.358%) per quarter. An effect was also found for “Quintile 2”, 0.213% (95% CI 0.003% to 0.422%), and “Quintile 1”, 0.259% (95% CI 0.111% to 0.407%).

The South West experienced an average decrease in pre-school booster uptake for “Least deprived 20% (Quintile 5)” after lockdown per quarter of 0.238% (95% CI -0.382% to -0.093%). There was evidence of a lockdown-associated average increase in uptake for the South East for local authorities in “Quintile 2”, by an average of 0.168% (95% CI 0.013 to 0.322), and in the context of East of England and “Quintile 4”, by 0.185% (95% CI 0.026% to 0.345%).

No additional main effect of Phase 1 or Phase 2 COVID-19 vaccination rollout was identified, and no statistically significant changes for specific deprivation quintiles for these events.

Figure 4.11

Pre-school booster uptake across the study period from April – June to July – September 2014 to April – June 2022 across deprivation quintiles, disaggregated by region (2019 Sep is missing data).





Time, measured in financial quarters

Furthermore, there is evidence to support a main lockdown-associated effect on MMR vaccine uptake per quarter compared to London for Yorkshire and the Humber, with an average decline of 0.195% (95% CI -0.28% to -0.111%), the North West, 0.182% (95% CI -0.161% to -0.004%), the East Midlands, 0.187% (95% CI -0.331% to -0.043%), the West Midlands, 0.122% (95% CI -0.215% to -0.029%), and the East of England, 0.099% (95% CI -0.192% to -0.006%). However, the South West saw an increase of 0.157% (95% CI 0.54% to 0.26%) per quarter associated with the first lockdown.

The interaction between lockdown, region, deprivation, and MMR vaccine uptake exhibited several statistically significant findings. Local authorities in the North East, classified as “Quintile 2”, experienced an average increase in uptake of 0.203% (95% CI 0.082% to 0.324%) per quarter, and “Most deprived 20% (Quintile 1)”, with a similar increase of 0.296% (95% CI 0.176% to 0.415%), when compared to London and “Quintile 3”.

For “Least deprived 20% (Quintile 5)”, an average increase of 0.3% (95% CI 0.17% to 0.429%) per quarter for Yorkshire and the Humber was found, as for “Quintile 2”, a 0.346% increase (95% CI 0.228% to 0.463%), and “Most deprived 20% (Quintile 1)”, a 0.329% increase (95% CI 0.204% to 0.455%).

In the context of the North West for local authorities classified as “Quintile 4”, an average increase in uptake of 0.217% (95% CI 0.095% to 0.338%) per quarter compared to London and “Quintile 3”. This effect was also evident for “Quintile 2”, with an average increase of 0.223% (95% CI 0.106% to 0.341%) and the “Most deprived 20% (Quintile 1)”, 0.14% (95% CI 0.36% to 0.244%).

For the East Midlands, “Least deprived 20% (Quintile 5)”, there was a 0.257% increase (95% CI 0.074% to 0.044%) in MMR vaccination uptake, as evident for “Quintile 4”, 0.245% (95% CI 0.079% to 0.0412%), and “Most deprived 20% (Quintile 1)”, 0.192% (95% CI 0.012% to 0.372%).

Evidence suggests a positive lockdown effect for “Quintile 4” local authorities in the West Midlands, with an average increase of 0.229% (95% CI 0.107% to 0.351%) per quarter. An effect was also found for “Quintile 2”, 0.262% (95% CI 0.089% to 0.434%), and “Most deprived 20% (Quintile 1)”, 0.254% (95% CI 0.132% to 0.375%).

There was evidence of a lockdown-associated average increase in uptake for the South East for local authorities in “Least deprived 20% (Quintile 5)” by an average of 0.124% (95% CI 0.004% to 0.243%), and “Quintile 2”, 0.174% (95% CI 0.046% to 0.301%).

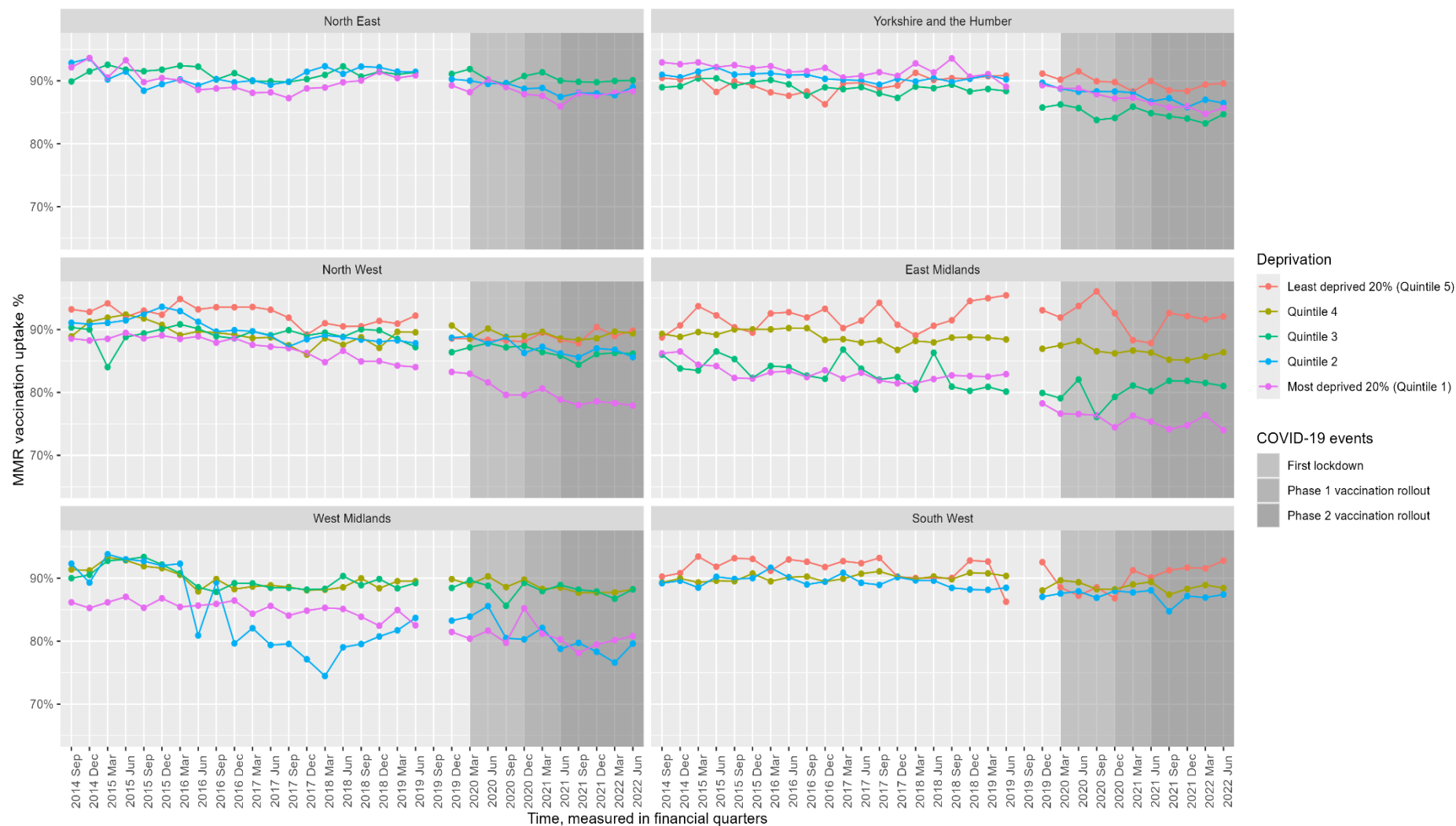
In the context of East of England and “Least deprived 20% (Quintile 5)” local authorities, MMR vaccination uptake increased by an average of 0.148% (95% CI 0.013% to 0.283%) per quarter when compared to London and “Quintile 3”. The results also supported a lockdown effect for “Quintile 4”, demonstrating an average increase of 0.206% (95% CI 0.074% to 0.337%).

In summary, “Region” does impact the effect of deprivation and COVID-19 events on childhood vaccination uptake. In the context of lockdown, two of the most deprived regions (the North East and West Midlands) had greater uptake for both the pre-school booster and MMR vaccine uptake in their “Most deprived 20% (Quintile 1)” when compared to London and “Quintile 3”. The North East and West Midlands are described as more deprived regions because they do not have local authorities classified as “Least deprived 20% (Quintile 5)”, unlike the other seven. Additionally, two of the least deprived regions (South East and South West – no local authorities classified as “Most deprived 20% (Quintile 1)”) did not exhibit significant lockdown and “Quintile 4” interaction effects, meaning there is no evidence to suggest greater uptake in this context compared to London. Given this, it can be inferred that equally deprived areas across England experienced different lockdown-associated changes in vaccination uptake. For instance, for lockdown effects associated with “Quintile 2”, there was no evidence suggesting that East of England outperformed London and “Quintile 3”. However, the North East saw a 0.296% (95% CI 0.082% to 0.324%) average increase in uptake per quarter.

Lastly, no additional main effects of Phase 1 or Phase 2 COVID-19 vaccination rollout were identified, and there were no statistically significant changes for specific deprivation quintiles for these events. The adjusted R^2 values were 16.79% and 22.24% for the pre-school booster and MMR vaccine, respectively. This suggests that regional variation explains more of the variation in uptake for the MMR vaccine than the pre-school booster when it is not included (main models adjusted R^2 : pre-school booster = 12.8%, MMR = 19.48%).

Figure 4.12

MMR vaccine uptake across the study period from April – June to July – September 2014 to April – June 2022 across deprivation quintiles, disaggregated by region (2019 Sep is missing data).





Time, measured in financial quarters

4.4.8. Findings: robustness testing

This section discusses some of the results of the robustness tests, which are important for assessing the reliability of the findings. Additional robustness tests are reported in Appendices 4.23, 4.24, 4.25, and 4.26. The first robustness test performed was removing the “*nChild*” control variable (indicating the number of total vaccine-eligible children in each local authority per quarter). The results are presented in Table 4.12. The results demonstrate the importance of the control variable, evident by lower adjusted- R^2 values (main models adjusted R^2 : pre-school booster = 12.8%, MMR = 19.48%, no-control models adjusted R^2 : pre-school booster = 11.07%, MMR = 17.64%). The models that exclude the control variable have lower explanatory power, justifying its inclusion in the analyses.

Table 4.12

The results of a fixed effects linear piecewise regression analysing pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events (no controls).

Piecewise regression of pre-school booster vaccination uptake				
	Adjusted R ² = 11.07%	estimate	95% CI	
Time		-0.092%	-0.109%	-0.074% ***
Lockdown (ref. Quintile 3)		0.007%	-0.025%	0.040%
<i>Lockdown: Least deprived 20% (Quintile 5)</i>		0.027%	-0.017%	0.070%
<i>Lockdown: Quintile 4</i>		-0.010%	-0.054%	0.034%
<i>Lockdown: Quintile 2</i>		-0.054%	-0.097%	-0.010%
<i>Lockdown: Most deprived 20% (Quintile 1)</i>		-0.159%	-0.203%	-0.116%
Phase 1 Vaccination Rollout (ref. Quintile 3)		0.040%	-0.015%	0.094%
<i>Phase 1: Least deprived 20% (Quintile 5)</i>		-0.009%	-0.086%	0.069%
<i>Phase 1: Quintile 4</i>		-0.009%	-0.086%	0.068%
<i>Phase 1: Quintile 2</i>		-0.014%	-0.091%	0.063%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>		-0.008%	-0.085%	0.069%
Phase 2 Vaccination Rollout (ref. Quintile 3)		-0.027%	-0.077%	0.023%
<i>Phase 2: Least deprived 20% (Quintile 5)</i>		0.027%	-0.044%	0.098%
<i>Phase 2: Quintile 4</i>		0.014%	-0.057%	0.084%
<i>Phase 2: Quintile 2</i>		0.016%	-0.054%	0.087%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>		0.007%	-0.063%	0.078%
Piecewise regression of MMR vaccination uptake				
	Adjusted R ² = 17.64%	estimate	95% CI	
Time		-0.081%	-0.095%	-0.066% ***
Lockdown (ref. Quintile 3)		0.005%	-0.021%	0.032%
<i>Lockdown: Least deprived 20% (Quintile 5)</i>		0.047%	0.012%	0.083%
<i>Lockdown: Quintile 4</i>		-0.024%	-0.060%	0.012%
<i>Lockdown: Quintile 2</i>		-0.061%	-0.097%	-0.025%
<i>Lockdown: Most deprived 20% (Quintile 1)</i>		-0.154%	-0.190%	-0.118%
Phase 1 Vaccination Rollout (ref. Quintile 3)		0.029%	-0.015%	0.074%
<i>Phase 1: Least deprived 20% (Quintile 5)</i>		-0.028%	-0.092%	0.035%
<i>Phase 1: Quintile 4</i>		-0.003%	-0.066%	0.061%
<i>Phase 1: Quintile 2</i>		-0.029%	-0.092%	0.034%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>		-0.015%	-0.078%	0.049%
Phase 2 Vaccination Rollout (ref. Quintile 3)		-0.029%	-0.070%	0.012%
<i>Phase 2: Least deprived 20% (Quintile 5)</i>		0.012%	-0.047%	0.070%
<i>Phase 2: Quintile 4</i>		0.010%	-0.048%	0.068%
<i>Phase 2: Quintile 2</i>		0.024%	-0.034%	0.082%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>		0.016%	-0.042%	0.074%
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$				

The second robustness test exchanged fixed effects for random effects. However, performing a fixed-effects model and clustering the standard errors by local authorities is computationally similar to a random-effects model, as evident in Table 4.13.

Table 4.13

The results of a random effects linear piecewise regression analysing pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events.

Piecewise regression of pre-school booster vaccination uptake				
	estimate	95% CI		
Time	-0.097%	-0.115%	-0.080%	***
Lockdown (ref. Quintile 3)	0.005%	-0.027%	0.038%	
<i>Lockdown: Least deprived 20% (Quintile 5)</i>	0.025%	-0.018%	0.068%	
<i>Lockdown: Quintile 4</i>	-0.008%	-0.051%	0.035%	
<i>Lockdown: Quintile 2</i>	-0.054%	-0.097%	-0.011%	*
<i>Lockdown: Most deprived 20% (Quintile 1)</i>	-0.158%	-0.201%	-0.115%	***
Phase 1 Vaccination Rollout (ref. Quintile 3)	0.041%	-0.013%	0.095%	
<i>Phase 1: Least deprived 20% (Quintile 5)</i>	-0.005%	-0.082%	0.072%	
<i>Phase 1: Quintile 4</i>	-0.006%	-0.082%	0.071%	
<i>Phase 1: Quintile 2</i>	-0.015%	-0.092%	0.061%	
<i>Phase 1: Most deprived 20% (Quintile 1)</i>	-0.008%	-0.084%	0.069%	
Phase 2 Vaccination Rollout (ref. Quintile 3)	-0.031%	-0.080%	0.019%	
<i>Phase 2: Least deprived 20% (Quintile 5)</i>	0.025%	-0.045%	0.096%	
<i>Phase 2: Quintile 4</i>	0.008%	-0.062%	0.078%	
<i>Phase 2: Quintile 2</i>	0.018%	-0.052%	0.088%	
<i>Phase 2: Most deprived 20% (Quintile 1)</i>	0.007%	-0.063%	0.077%	
Piecewise regression of MMR vaccine uptake				
	estimate	95% CI		
Time	-0.086%	-0.101%	-0.072%	***
Lockdown (ref. Quintile 3)	0.003%	-0.023%	0.030%	
<i>Lockdown: Least deprived 20% (Quintile 5)</i>	0.046%	0.010%	0.081%	*
<i>Lockdown: Quintile 4</i>	-0.022%	-0.058%	0.013%	
<i>Lockdown: Quintile 2</i>	-0.061%	-0.097%	-0.026%	**
<i>Lockdown: Most deprived 20% (Quintile 1)</i>	-0.153%	-0.188%	-0.118%	***
Phase 1 Vaccination Rollout (ref. Quintile 3)	0.031%	-0.014%	0.075%	
<i>Phase 1: Least deprived 20% (Quintile 5)</i>	-0.025%	-0.088%	0.038%	
<i>Phase 1: Quintile 4</i>	0.001%	-0.062%	0.064%	
<i>Phase 1: Quintile 2</i>	-0.030%	-0.093%	0.033%	
<i>Phase 1: Most deprived 20% (Quintile 1)</i>	-0.014%	-0.077%	0.048%	
Phase 2 Vaccination Rollout (ref. Quintile 3)	-0.033%	-0.073%	0.008%	
<i>Phase 2: Least deprived 20% (Quintile 5)</i>	0.010%	-0.048%	0.068%	
<i>Phase 2: Quintile 4</i>	0.004%	-0.053%	0.062%	
<i>Phase 2: Quintile 2</i>	0.026%	-0.032%	0.083%	

<i>Phase 2: Most deprived 20% (Quintile 1)</i>	0.016%	-0.041%	0.073%
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$			
Control variables: Number of vaccine-eligible children in a local authority each quarter.			

The third and fourth robustness tests used different operationalisations of deprivation, such as deciles (Table 4.14) and a continuous version (Table 4.15). The adjusted R^2 values for the models employing deciles do not demonstrate large differences in comparison to the main models using quintiles: main models adjusted R^2 : pre-school booster = 12.8%, MMR = 19.48%, models using deciles R^2 : pre-school booster = 13.04%, MMR = 19.58%. A balance must be struck between the ease of interpretation and statistical power. Using deciles can produce substantially more statistically significant coefficients, which require interpretation in exchange for a small improvement in the adjusted R^2 .

Table 4.14

The results of a fixed effects linear piecewise regression analysing pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation deciles and COVID-19 events.

Piecewise regression of pre-school booster vaccine uptake				
	Adjusted R^2 = 13.04%	estimate	95% CI	
Time		-0.101%	-0.119%	-0.084% ***
Lockdown (ref. Quintile 5)		-0.014%	-0.059%	0.030%
<i>Lockdown: Least deprived 20% (Quintile 10)</i>		0.112%	0.051%	0.173% ***
<i>Lockdown: Quintile 9</i>		-0.028%	-0.089%	0.033%
<i>Lockdown: Quintile 8</i>		0.017%	-0.044%	0.078%
<i>Lockdown: Quintile 7</i>		0.007%	-0.054%	0.067%
<i>Lockdown: Quintile 6</i>		0.037%	-0.024%	0.098%
<i>Lockdown: Quintile 4</i>		-0.043%	-0.104%	0.018%
<i>Lockdown: Quintile 3</i>		-0.028%	-0.089%	0.033%
<i>Lockdown: Quintile 2</i>		-0.133%	-0.194%	-0.072% ***
<i>Lockdown: Most deprived 20% (Quintile 1)</i>		-0.144%	-0.205%	-0.083% ***
Phase 1 Vaccination Rollout (ref. Quintile 5)		0.036%	-0.040%	0.112%
<i>Phase 1: Least deprived 20% (Quintile 10)</i>		-0.052%	-0.160%	0.056%
<i>Phase 1: Quintile 9</i>		0.055%	-0.054%	0.165%
<i>Phase 1: Quintile 8</i>		-0.001%	-0.109%	0.107%
<i>Phase 1: Quintile 7</i>		0.006%	-0.102%	0.114%
<i>Phase 1: Quintile 6</i>		0.011%	-0.097%	0.119%
<i>Phase 1: Quintile 4</i>		-0.016%	-0.124%	0.092%
<i>Phase 1: Quintile 3</i>		-0.004%	-0.112%	0.103%
<i>Phase 1: Quintile 2</i>		-0.017%	-0.125%	0.091%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>		0.013%	-0.095%	0.121%
Phase 2 Vaccination Rollout (ref. Quintile 5)		-0.026%	-0.096%	0.043%

<i>Phase 2: Least deprived 20% (Quintile 10)</i>	0.011%	-0.088%	0.109%	
<i>Phase 2: Quintile 9</i>	0.026%	-0.075%	0.126%	
<i>Phase 2: Quintile 8</i>	0.008%	-0.091%	0.106%	
<i>Phase 2: Quintile 7</i>	-0.012%	-0.111%	0.087%	
<i>Phase 2: Quintile 6</i>	-0.013%	-0.111%	0.086%	
<i>Phase 2: Quintile 4</i>	0.024%	-0.075%	0.123%	
<i>Phase 2: Quintile 3</i>	0.001%	-0.098%	0.100%	
<i>Phase 2: Quintile 2</i>	0.013%	-0.085%	0.112%	
<i>Phase 2: Most deprived 20% (Quintile 1)</i>	-0.012%	-0.111%	0.086%	
Piecewise regression of MMR vaccine uptake				
	Adjusted R ² = 19.58%	<i>estimate</i>	<i>95% CI</i>	
Time		-0.089%	-0.103%	-0.075% ***
Lockdown (ref. Quintile 5)		-0.031%	-0.067%	0.006%
<i>Lockdown: Least deprived 20% (Quintile 10)</i>		0.092%	0.042%	0.142% ***
<i>Lockdown: Quintile 9</i>		0.063%	0.013%	0.113% *
<i>Lockdown: Quintile 8</i>		0.000%	-0.050%	0.050%
<i>Lockdown: Quintile 7</i>		0.024%	-0.026%	0.074%
<i>Lockdown: Quintile 6</i>		0.066%	0.016%	0.116% *
<i>Lockdown: Quintile 4</i>		-0.014%	-0.064%	0.036%
<i>Lockdown: Quintile 3</i>		-0.043%	-0.093%	0.007%
<i>Lockdown: Quintile 2</i>		-0.110%	-0.160%	-0.060% ***
<i>Lockdown: Most deprived 20% (Quintile 1)</i>		-0.128%	-0.178%	-0.078% ***
Phase 1 Vaccination Rollout (ref. Quintile 5)		0.037%	-0.026%	0.099%
<i>Phase 1: Least deprived 20% (Quintile 10)</i>		-0.031%	-0.119%	0.058%
<i>Phase 1: Quintile 9</i>		-0.029%	-0.119%	0.060%
<i>Phase 1: Quintile 8</i>		-0.011%	-0.099%	0.078%
<i>Phase 1: Quintile 7</i>		0.004%	-0.084%	0.093%
<i>Phase 1: Quintile 6</i>		-0.012%	-0.100%	0.077%
<i>Phase 1: Quintile 4</i>		-0.051%	-0.140%	0.037%
<i>Phase 1: Quintile 3</i>		-0.021%	-0.109%	0.068%
<i>Phase 1: Quintile 2</i>		-0.035%	-0.124%	0.053%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>		-0.004%	-0.093%	0.084%
Phase 2 Vaccination Rollout (ref. Quintile 5)		-0.029%	-0.086%	0.028%
<i>Phase 2: Least deprived 20% (Quintile 10)</i>		-0.003%	-0.084%	0.077%
<i>Phase 2: Quintile 9</i>		0.013%	-0.070%	0.095%
<i>Phase 2: Quintile 8</i>		0.011%	-0.070%	0.091%
<i>Phase 2: Quintile 7</i>		-0.018%	-0.099%	0.063%
<i>Phase 2: Quintile 6</i>		-0.010%	-0.091%	0.070%
<i>Phase 2: Quintile 4</i>		0.032%	-0.049%	0.113%
<i>Phase 2: Quintile 3</i>		0.011%	-0.070%	0.092%
<i>Phase 2: Quintile 2</i>		0.025%	-0.056%	0.106%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>		-0.003%	-0.084%	0.077%

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Control variables: Number of vaccine-eligible children in a local authority each quarter.

Similarly, when the operationalisation of deprivation is continuous, the R^2 values (pre-school booster = 12.25%, MMR = 18.7%) do not differ considerably from main models (pre-school booster = 12.8%, MMR = 19.48%) and are slightly reduced; thus quintiles are preferred. Also, a continuous operationalisation would not adequately capture if the association with deprivation is non-linear.

Table 4.15

The results of a fixed effects linear piecewise regression analysing pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation as a continuous variable and COVID-19 events.

Piecewise regression of pre-school booster vaccine uptake				
	Adjusted R^2 = 12.25%	estimate	95% CI	
Time		-0.101%	-0.119%	-0.084% ***
Lockdown		-0.142%	-0.171%	-0.112% ***
<i>Lockdown: deprivation rank</i>		0.001%	0.001%	0.002% ***
Phase 1 Vaccination Rollout		0.037%	-0.011%	0.086%
<i>Phase 1: deprivation rank</i>		0.000%	-0.001%	0.001%
Phase 2 Vaccination Rollout		-0.029%	-0.073%	0.016%
<i>Phase 2: deprivation rank</i>		0.000%	0.000%	0.001%
Piecewise regression of MMR vaccine uptake				
	Adjusted R^2 = 18.7%	estimate	95% CI	
Time		-0.089%	-0.104%	-0.075% ***
Lockdown		-0.147%	-0.171%	-0.123% ***
<i>Lockdown: deprivation rank</i>		0.001%	0.001%	0.002% ***
Phase 1 Vaccination Rollout		0.020%	-0.020%	0.060%
<i>Phase 1: deprivation rank</i>		0.000%	0.000%	0.000%
Phase 2 Vaccination Rollout		-0.016%	-0.052%	0.021%
<i>Phase 2: deprivation rank</i>		0.000%	0.001%	0.000%
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$				
Control variables: Number of vaccine-eligible children in a local authority each quarter.				

The remainder of the robustness tests are presented in the Appendices, such as the non-lagged effect of Phase 1 COVID-19 vaccination rollout (Appendix 4.23), modelling further non-COVID-19 non-linearity (Appendix 4.24), exchanging the deprivation reference category from “Quintile 3” to “Most deprived 20% (Quintile 1)” (Appendix 4.25), and using polynomial spline terms instead of linear piecewise terms (Appendix 4.26). One notable finding of these robustness tests was exchanging the reference category from “Quintile 3” to “Most deprived 20% (Quintile 1)” (Appendix 4.26). For the pre-school booster,

“Quintile 3” experienced a significant association with lockdown, increasing by an average of 0.157% (95% CI 0.114 to 0.2) per quarter. Whilst still an increase, “Quintile 4” exhibited a 0.15% (95% CI 0.107 to 0.193) increase per quarter. For the MMR vaccine, this difference was starker, with an increase by an average of 0.152% (95% CI 0.117 to 0.188) for “Quintile 3” but only 0.131% (95% CI 0.096% to 0.167%) for “Quintile 4”. This demonstrates that the association between vaccination uptake and socioeconomic deprivation may not always adhere to a clear, explicit social gradient.

4.5. Discussion

4.5.1. Addressing the hypotheses

This section briefly recaps the main findings and details the limitations of the analyses before making some concluding statements. The main discussion of the quantitative results is presented in Chapter 6, where they are integrated with the qualitative findings.

The objective of this chapter was as follows:

Objective 2 – Quantitatively analyse whether there has been a change in socioeconomic inequalities in childhood vaccination uptake in England associated with the COVID-19 pandemic.

To address this objective, three hypotheses were formulated to guide the analysis, detailed below:

Hypothesis 1

H₀: There are no changes in 0-5 childhood vaccination uptake from September 2014 to March 2022.

H₁: There are changes in 0-5 childhood vaccination uptake from September 2014 to March 2022.

The exploratory analysis suggested that the uptake of pre-school boosters and MMR vaccinations in England had declined before COVID-19. Still, the rate of this decline appeared to increase around this event. It also suggested that different socioeconomic groups and regions may differ in their experience of childhood vaccination uptake. The

piecewise regressions identified an overall lockdown-associated decline in vaccination uptake. This was not found for Phase 1 or Phase 2 COVID-19 vaccination rollout.

Hypothesis 2

H₀: The change in 0-5 vaccination uptake during the COVID-19 pandemic is not affected by the deprivation level of a local authority.

H₁: The change in 0-5 vaccination uptake during the COVID-19 pandemic is affected by the deprivation level of a local authority.

Regarding Hypothesis 2, the deprivation level of a local authority appeared to affect the change in uptake during COVID-19. The results suggested more evidence of lockdown-associated socioeconomic inequalities in vaccination uptake for both the pre-school booster and the MMR vaccine. However, these effects were more prominent in the context of the MMR vaccine – greater uptake for the least deprived and lower uptake for the most deprived local authorities.

Evidence suggests that a clear, explicit social gradient may not exist for childhood vaccination uptake. If this were the case, it would be expected that “Quintile 4” would exhibit a statistically significant increase in uptake (considering the reference category was “Quintile 3”). Also, in the robustness test where the reference category was changed to “Most deprived 20% (Quintile 1)” (the results are presented in Appendix 4.25), the results support this claim.

Hypothesis 3

H₀: The change in 0-5 vaccination uptake during the COVID-19 pandemic associated with the deprivation level of a local authority does not differ across regions.

H₁: The change in 0-5 vaccination uptake during the COVID-19 pandemic associated with the deprivation level of a local authority differs across regions.

In reference to Hypothesis 3, the results demonstrated regional differences in COVID-19-associated socioeconomic inequalities in childhood vaccination uptake. London consistently achieved lower uptake levels for both the pre-school booster and MMR vaccine, as ascertained in the exploratory and main analyses. The piecewise regressions, including and excluding local authorities in London, demonstrated similar findings.

However, when excluded, there was stronger evidence of socioeconomic inequalities in vaccination – greater uptake for the least deprived local authorities and lower uptake for the most deprived. This suggests London could be an outlier.

Additional analyses that included regional identifiers in the interaction terms were performed to explore this issue further. In the context of lockdown, two of the most deprived regions (the North East and West Midlands) had greater uptake for both the pre-school booster and MMR vaccine uptake in their “Most deprived 20% (Quintile 1)” when compared to London and “Quintile 3”. Additionally, two of the least deprived regions did not exhibit significant lockdown and “Quintile 4” interaction effects, meaning there is no evidence to suggest greater uptake in this context compared to London. Given this, it can be inferred that equally deprived areas across England experienced lockdown-associated changes in uptake differently.

Overall, the MMR vaccine appears more susceptible to socioeconomic differences in uptake than the pre-school booster, regardless of deprivation level or region. While there were lockdown-associated effects on uptake, Phase 1 and Phase 2 COVID-19 vaccination rollout exhibited no additional impact.

The following section explores only the limitations of this quantitative component; the strengths are presented in Chapter 6, where they can be adequately demonstrated in the context of a mixed methods project.

4.5.2. Limitations

This study has three main limitations; the first one has already been discussed in Section 4.2.2, *COVER and CPRD: strengths and limitations*, namely, ecological fallacy. Using area-level measures to represent populations does not reflect the nuance because individuals are generalised by a single label. Therefore, the findings must be treated with caution and do not reflect the unique circumstances of all individuals.

Secondly, this study used quarterly uptake data, making it difficult to discern the specific effect of certain events, such as the pandemic. Data published in monthly increments would be more useful for this type of research. Additionally, the quarterly data caused some convergence issues. The discrepancy between the publication (or “evaluation”)

quarter of COVER data reflects vaccines administered for the pre-school booster and MMR vaccine 20 months prior. Thus, the data needed to be lagged by six or seven quarters. A lag of seven quarters was chosen because this reflects when the majority of eligible children would have been vaccinated, although it must be recognised that this may not be the case for all. Unfortunately, this is unavoidable when using quarterly data not published in the quarter following administration.

The third limitation is acknowledging that uptake declined before COVID-19, but this was not explored in this study. A robustness test was performed to explore prior fluctuations in uptake (Appendix 4.24), and results similar to those of the main models were demonstrated. Nevertheless, investigating these declines may help to understand why this trend predates the pandemic. This is discussed further in Chapter 6.

4.5.3. Implications for the qualitative component

One purpose of the quantitative study was to identify a geographical focus for the qualitative inquiry. Although London is an outlier, Chapter 3 ascertained that there were studies already published on the effects of COVID-19 on childhood vaccination uptake. Thus, further research into this region was not needed.

In the exploratory analysis, the North East was found to have outperformed any other regions for five of the seven childhood vaccines. The main analyses also identified that, in the context of lockdown, two of the most deprived regions (the North East and West Midlands) had greater uptake for both the pre-school booster and MMR vaccination uptake in their most deprived local authorities. Considering this, a deeper exploration into the North East is warranted – why do they outperform other regions despite their higher levels of socioeconomic deprivation? Could this be linked to inverse associations (higher uptake for more deprived areas)?

Specific interview questions can be asked of professionals involved in delivering, commissioning, supporting, and monitoring the childhood vaccination programme regarding the overall lower uptake of the pre-school booster and the MMR vaccine. This approach would provide a unique perspective on the topic.

4.5.4. Conclusion

In conclusion, the results demonstrated a widening of socioeconomic inequalities in childhood vaccination uptake associated with COVID-19. They also suggested that national vaccination uptake analyses must account for regional variation because equally deprived local authorities do not perform the same across different regions. Although this is not necessarily a new finding, it furthers the literature on health divides in England in the context of childhood vaccination uptake. This knowledge can be applied to other healthcare interventions which may adhere to similar patterns.

This chapter has presented the methods and results of a statistical analysis of childhood vaccination uptake and its association with the COVID-19 pandemic and socioeconomic deprivation; it represents the quantitative component of the mixed methods study. Chapter 5 outlines the approach and findings of the qualitative component, and Chapter 6 integrates these results.

Chapter 5. **Andrew Wakefield “did more damage for the health and well-being of both children and the wider community than any other doctor other than Harold Shipman”**: Qualitative Interviews Exploring Childhood Vaccination Programme Delivery in the North East of England.

5.1. Introduction

5.1.1. *Chapter overview*

Chapter 4 revealed that childhood vaccination experienced a COVID-19 lockdown-associated increase in socioeconomic inequalities in uptake. It demonstrated that local authorities with similar levels of deprivation did not perform consistently across England. The North East exhibited greater uptake levels despite the increased prevalence of socioeconomically deprived local authorities. Subsequently, further investigation into the North East was suggested to explore why. Chapter 5 presents the methodological approach and findings of a qualitative interview study exploring the delivery of the childhood vaccination programme, with a specific focus on areas of high socioeconomic deprivation. In doing so, this addresses the third thesis objective, which was adapted to reflect the refined geographical focus, as follows:

Objective 3 – Qualitatively explore the landscape of delivering, commissioning, supporting, and monitoring the childhood vaccination programme in the **North East of England** with a specific focus on areas of high socioeconomic deprivation.

This chapter first presents a brief overview of the interview setting and the research questions before detailing the study design. Then, the sampling frame and recruitment process are discussed before outlining the ethical approval process. Afterwards, the interview guide, transcript coding, and framework analysis are explored. The findings are then presented. An overview of the interview process is provided, including anonymised participant information. Then, the identified themes are stated before proceeding to the in-depth analysis. Finally, the research questions are addressed, followed by the methodological limitations.

5.1.2. The North East of England: a brief history

Although there can be social debates over the areas considered “North” and “South” in England, from an administrative perspective, the “North” includes North West, North East, and Yorkshire and the Humber regions (Bambra *et al.*, 2023). On average, Northern areas are more socioeconomically deprived than Southern regions, a fact that is commonly discussed in the literature (Bambra *et al.*, 2023; Bernard, McGowan and Bambra, 2024; Fairbrother *et al.*, 2024; Hacking, Muller and Buchan, 2011; Townsend, Phillimore and Beattie, 2023; Children's Commissioner for England, 2018; Bambra, Barr and Milne, 2014). The North was reportedly more economically impacted by COVID-19 (Bambra *et al.*, 2023), and Brexit (Los *et al.*, 2017). As well as socioeconomic inequalities, the North-South health divide is an established phenomenon where, on average, health in Southern areas is better than in Northern regions (Bambra, Barr and Milne, 2014).

“The scale of the divide is such that the life expectancy gap for women between the poorest English regions—the North East (NE) and North West (NW)—and the richest—London and the South East—was similar to the gap between the former West Germany and post-communist East Germany in the mid-1990s.” (Bambra, Barr and Milne, 2014, p. 183).

Within the North, the North East experiences further disadvantage. The 2021 Census estimated a population of 2,647,000 (rounded to the nearest 100), meaning it is the least populated region in the country (Office for National Statistics, 2021). It is also the least ethnically diverse, with 90.6% identifying as white British in 2021 (GOV.UK, 2022). In 2023, 8.5% of the adult population had no educational qualifications, the highest prevalence of any other region and 2.3% above the national average (Office for National Statistics, 2023). Additionally, healthy life expectancy in the area is the lowest of any other region, at 59.7 years for women (4.2 years less than the national average) and 59.1 years for males (4 years less than the national average) (Office for National Statistics, 2023). There are pockets of exceptionally high socioeconomic deprivation within the North East, such as the local authority of Middlesbrough. Research suggests *“deindustrialisation, austerity, and poor housing stock”* (Price *et al.*, 2024, p. 4) has contributed to the highest rate of deaths related to suicide, alcohol, and drug overdoses in Middlesbrough.

In Sections 1.1.2, *The unequal pandemic*, and 1.2.2, *Socioeconomic inequalities in health and healthcare*. It was discussed how there is a social gradient of health, where

those experiencing high socioeconomic deprivation have poorer health outcomes and healthcare interactions. Additionally, they were more at risk of adverse COVID-19 outcomes (disease prevalence, low vaccination uptake, and associated mortality and morbidity). However, there is a lack of research that brings these factors together and investigates them in the context of the childhood vaccination programme in a post-COVID-19 context. This qualitative study attempts to fill this gap.

5.1.3. Research questions

Section 3.3, *Literature review*, suggested there is a lack of studies focusing on childhood vaccination uptake in regions other than London. Despite rigorous database searching, one article focusing on the North East was identified: A qualitative interview study by Price *et al.* (2022). The study sought parents' opinions regarding the barriers and facilitators to childhood flu vaccination uptake. Authors found that parents of unvaccinated children did not necessarily hold vaccine-hesitant views, but several access barriers made the process difficult. The two most prominent barriers were limited appointment opportunities for immunisation and vaccination not being a priority for busy parents. While this study focused on childhood vaccination and the North East, there is still scope for a service delivery perspective in a post-COVID-19 context. To address Objective 3, the following research questions were formulated:

Research Question 1: What insight do professionals involved in commissioning and monitoring the childhood immunisation programme in the North East of England have into potential reasons for the comparatively higher levels of childhood vaccination uptake?

Research Question 2: What are the realities experienced by professionals in delivering the childhood vaccination programme in areas of high socioeconomic deprivation in the North East of England?

Research Question 3: What are the opinions of professionals involved in delivering, commissioning, supporting, and monitoring the childhood vaccination programme on current initiatives and interventions to improve provision in the North East of England, with a focus on areas of high socioeconomic deprivation?

5.2. Methods

5.2.1. Study design

The reporting of the interview study followed Tong *et al.*'s (2007) consolidated criteria for reporting qualitative research (COREQ) checklist. COREQ is used to ensure explicit and comprehensive reporting of qualitative studies. A completed copy of this checklist can be viewed in Appendix 5.1.

The research questions were addressed using semi-structured interviews. Semi-structured interviews utilise both open and closed questions, allowing a guided discussion that will answer the research questions and provide opportunities for follow-ups, “*planned but flexible*” (Carter and Henderson, 2005, p. 218). Flexibility was needed so the interview guide could be adapted to the different professional roles of the interviewees (delivering, commissioning, supporting, and monitoring the childhood vaccination programme) whilst ensuring the same topics were addressed. After participants selected a suitable date and time to be interviewed, a completed consent form was obtained (see Section 5.2.1, *Ethical considerations*). All interviews were conducted by myself using Zoom or Microsoft Teams, depending on the participant's preference, and were audio-video recorded using the built-in facilities.

Using video calling software to conduct qualitative interviews increased in popularity during the COVID-19 pandemic (Oliffe *et al.*, 2021). One of the most important features of a successful interview is building rapport between the interviewer and interviewee. However, the ability of video calling software to promote a natural rapport is debated (Weller, 2017). In their study using Zoom for qualitative data collection, Archibald *et al.* (2019) found that 69% of their participants felt they were able to form and maintain an adequate rapport. The authors also cited that an advantage of using video calling software is greater flexibility regarding timing and location. This is especially applicable when interviewing participants in their professional capacity during restrictive working hours. Another consideration when conducting interviews via video calling software is the interviewee's technological skills (Archibald *et al.*, 2019). However, there is an increased likelihood of familiarity with computers and, by extension, video calling software when interviewing professionals. Indeed, there are other issues that cannot be

easily addressed, such as slow internet connection and poor-quality audio-visual equipment. In the context of this study, however, the benefits of using digital data collection methods outweighed the drawbacks, primarily due to the professional demands of the participants.

5.2.2. Sample

Eligible participants were professionals who delivered, commissioned, monitored or supported the childhood vaccination programme in the North East of England. This ensures the voices of those at different “levels” of the vaccination system are accounted for, as discussed in Section 3.2.1, *The English healthcare system* and Section 3.4.2, *Theory*. No eligibility restrictions were placed on, for example, years of career experience, length of time working in-post or any other criteria. The sampling frame included the following roles, teams, and organisations:

Regional level

- NHS England Screening and Immunisations Team North East and Yorkshire – responsible for commissioning the childhood programme in the region.
- Deep End Network NENC management – commissioners of a childhood immunisation intervention. A definition of the Deep End Network NENC, a justification of their participation, and an explanation of the childhood immunisation intervention are discussed in Section 5.2.3, *The Deep End Network North East and North Cumbria*.
- Service delivery partners – E.g., IntraHealth (proposed Deep End Network NENC childhood immunisation intervention provider) and North East of England Care System Support (NECS) (provides programme management for the Deep End Network NENC).

Local authority level

- Local Authority Public Health Teams in the North East – these professionals are not involved in delivering or commissioning the childhood programme, but they are responsible for the health and wellbeing of their child population (Local Government Association, 2024b). To be eligible, they were required to work

intimately with the promotion of childhood vaccination, assessed on a case-by-case basis.

Participants from the regional and local authority levels must have occupied an oversight role, such as a team leader or manager, or have had ownership over a relevant childhood-vaccination-related programme (E.g., involvement in interventions to increase uptake). Professionals who occupied lower-level roles were not eligible as they were less likely to be able to offer a broader perspective.

In-practice delivery level

- Nurses – primary administrators of childhood vaccinations.
- GPs and GP practice partners – secondary administrators of childhood vaccinations. GP practice partners may be involved with the programme's finances and/or safeguarding issues linked to missed vaccinations.
- Administrators – responsible for communicating with parents about their child's vaccinations and scheduling appointments.
- Practice, business and operations managers – oversee the childhood programme as an item of service, such as monitoring cash flow or implementing new policies (see Section 3.2.1, *The English healthcare system*).

5.2.3. The Deep End Network North East and North Cumbria

To ensure that in-practice delivery level professionals could provide insight into areas of high socioeconomic deprivation, participants were sampled from the Deep End Network North East and North Cumbria (NENC). The Deep End Network NENC is one of many Deep End organisations, both nationally and internationally (Wildman, Sowden and Norman, 2023). The GP networks originated in Scotland in 2009, created to support GPs working in areas of high socioeconomic deprivation through various pathways, such as policy advocacy and the commissioning of interventions (Butler *et al.*, 2022). It was recognised that patients living in these areas often have a significantly higher mortality rate and mental health-related morbidity than in less deprived areas (Butler *et al.*, 2022). Subsequently, the GPs serving these communities often experience a greater demand for appointments and, on average, care for more patients per GP, leading to increased stress

levels and burnout (Butler *et al.*, 2022). At the time of undertaking the research, identifying a Deep End GP practice is a two-step process: Firstly, all GP practices in England are ranked according to the percentage of their patient list who reside in the 15% most deprived Lower-layer Super Output Area (LSOA). This is defined using the Indices of Multiple Deprivation (IMD); see Section 4.2.3, *Socioeconomic position*, for more information.

The North East and North Cumbria Deep End Network was established in 2020. At the time of conducting the interviews (June 2023 to December 2023), there were 38 member GP practices in the following areas: Redcar, Cleveland and Middlesbrough (n = 16), County Durham (n = 6), Newcastle (n = 6), Sunderland (n = 3), Northumberland (n = 2), South Tyneside (n = 2), North Tyneside (n = 1), Gateshead (n = 1), and Stockton (n = 1). The NENC Network aims to bring together GPs serving the most deprived communities to share learning and ideas (Deep End NENC, 2023). The network is focused on working collaboratively to change how primary care is delivered, create positive change for practices, communities and patients, and advocate for wider systemic change in healthcare funding (Deep End NENC, 2023).

In 2023, the network was in the process of designing and commissioning an opt-in childhood immunisation catch-up intervention. They proposed two multi-disciplinary teams comprised of administrators and vaccination-trained nurses who would undertake a two-week rotation in each interested practice. Some of the suggested tasks the intervention team could perform were as follows:

- Identify and contact parents of unvaccinated children to arrange appointments.
- Offer extended clinical hours to provide more appointment diversity.
- Discuss vaccination concerns with parents.
- Provide a roving service that could vaccinate children in their homes.

The aim was to provide a flexible service each practice could tailor to its needs. The proposed provider was IntraHealth, who would utilise their adolescent school-age immunisation team. It was hoped the intervention would increase timely vaccination uptake and reduce the burden of delivering the programme through additional staffing. The intervention was rolled out in three cohorts from the week commencing 29th January

2024 for 6 months, starting in the Tees Valley. The interviews for this study were conducted before the service was rolled out.

I became aware of the intervention through my supervisor, Dr Sarah Sowden, the research lead for the Deep End Network NENC. The network needed to understand whether Deep End practices believed this intervention would benefit themselves, what orientation of the service would be most suitable (E.g., two nurses and one administrator or two nurses and no administrators), and whether there were any foreseeable implementation issues. Due to the alignment of my research interests with the intervention, I became a member of the research team to address both of our aims simultaneously. In doing so, it helped to address Research Question 3 (What are the opinions of professionals involved in delivering, commissioning, supporting, and monitoring the childhood vaccination programme on current initiatives and interventions to improve provision in the North East of England, with a focus on areas of high socioeconomic deprivation?) and provided a sampling frame for provider-level participants.

5.2.4. Sampling and recruitment

A purposive and snowball approach to sampling was taken. A purposive sample is a *“sample in which respondents, subjects, or settings are deliberately chosen to reflect some features or characteristics of interest”*, and a snowball sample, *“starting with an initial contact, the researcher asks this contact for referrals to other respondents who may be able to contribute to the research topic”* (Carter and Henderson, 2005, p. 226). To recruit regional and local authority-level participants, relevant professionals were contacted via email – referred to as an active recruitment (Negrin *et al.*, 2022) – some of which I had priorly established connections with. To recruit Deep End GP practice employees, the network's mailing list was used – an example of passive recruitment. Negrin *et al.* (2022) suggest that “laying the groundwork” and “building rapport” before data collection are important to successfully recruit participants for qualitative research. As a Deep End Network NENC research team member, I have a profile on their website (www.deependnenc.org/research/research-team/) and attending Deep End face-to-face networking events increased my visibility as a researcher.

Initial emails contained the participant information sheet (see Appendix 5.2) and requested further contact information from other professionals who may be eligible and willing if the recipient could not participate themselves. At the end of each interview, the same information was requested. This represents the snowball sampling aspect of recruitment. Snowball sampling was beneficial in mapping the process of vaccination without being influenced by preconceived ideas. With purposive and snowball sampling, there is a risk of homogeneity among the participants and their opinions (Robinson, 2014). However, this is not unavoidable when seeking to explore small, specific groups (E.g., North East team leaders/managers directly involved with the childhood vaccination programme).

5.2.5. Sample size and data saturation

The study aimed to recruit 20 interviewees in total: 10 for regional and local authority-level and 10 for provider-level professionals. However, recruitment would cease if data saturation were achieved before the 20 interviews were complete. Sample size and data saturation are intimately linked and contentious topics in qualitative research (Carter and Henderson, 2005; Saunders *et al.*, 2018; Sandelowski, 1995). There are no sample size quotas, but Sandelowski (1995) suggests the general consensus is not too few and not too many – not too few that the accounts cannot be effectively compared and contrasted, but not too many, rendering the data unmanageable. There are practical considerations (research team capacity), theoretical considerations (ensuring all important voices and perspectives are accounted for) and, in the context of mixed methods, the role of the qualitative component in relation to the quantitative.

Moreover, the concept of data saturation originates from Glaser and Strauss (2017, p. 61) who defines it as:

“The criterion for judging when to stop sampling the different groups pertinent to a category is the category’s theoretical saturation. Saturation means that no additional data are being found whereby the sociologist can develop properties of the category.”

Thus, data saturation refers to recruiting participants to ensure key perspectives are accounted for — however, Saunders *et al.* (2018) describes how data saturation can become confused with different but related concepts, such as *a priori* thematic

saturation. *A priori* thematic saturation “relates to the degree which identified codes or themes are exemplified in the data” (Saunders *et al.*, 2018, p. 1897). This is related to sampling; a researcher would cease to continue when the constructs that are being investigated have been satisfied (Francis *et al.*, 2010). This thesis utilised both data saturation and *a priori* thematic saturation.

On the other hand, O'Reilly and Parker (2012) argue that saturation debates, in general, are becoming a means by which qualitative researchers employ to conclude data collection without a true understanding of the implications. Authors further argue this applies a “one-size-fits-all” approach to qualitative research that is fundamentally contradictory to the essence of the paradigm (see Section 3.4.1, *Ontology and epistemology*, for more information on research paradigms). Nevertheless, there must be justification for ceasing qualitative data collection and/or analysis, and saturation debates are useful in the absence of sample size quotas.

5.2.1. Ethical considerations

All research has ethical considerations. Hammersley (2018, p. 23) argues that “*there is an understandable tendency today for many qualitative researchers' interest in ethical issues to focus heavily on gaining approval from ethics committees*” but that, fundamentally, ethics from a deontological perspective is concerned with what is morally right. These considerations go beyond avoiding harm, protecting anonymity and respecting autonomy, which are some common features of ethical approval processes (Hammersley, 2018), such as a moral obligation to portray participants' opinions accurately and authentically by not altering words or using them out of context. Another ethical consideration when conducting qualitative interviews is power dynamics. Power dynamics can create an uncomfortable environment for the participant if they feel patronised or minimised by the perceived status of the interviewer (Oakley, 2016). Given that only professionals were eligible to participate, this significantly reduces the risk of interviewer-interviewee power imbalances, as opposed to interviewing vulnerable groups (Oakley, 2016). Moreover, the topic of vaccination and COVID-19 can provoke a strong emotional response, which could have caused the participant's mild discomfort.

This was mitigated by looking for signs of visible distress, confirming with the participants they were comfortable, and pausing or ending the interview if required.

Considering the interviews were conducted remotely, the risk incurred from travelling and entering unfamiliar environments is not relevant to this study. However, this method incurs different ethical considerations primarily related to data protection and correct storage of audio-visual files (Salmons, 2016). The study adhered to the Data Protection Act 2018 and Newcastle University's data storage and handling protocols. Interview recordings were deleted after the analysis was completed, and the transcripts were thoroughly anonymised and will be destroyed after seven years.

All information about the study was provided in the participant information sheet (see Appendix 5.2), and a signed consent form was sought beforehand to confirm participants were comfortable to proceed (see Appendix 5.3). Both documents were modelled on those that had been successfully employed for other Deep End research studies, ensuring they adhered to common practices.

Ethical approval from the Newcastle University Faculty of Medical Sciences ethics board was sought and granted on 04/05/2023 until 31/10/2023 (Ref: 31864/2023). An extension was sought and granted on 23/10/2023, as recruitment was slower than anticipated, with the end date amended to 31/12/2023. The university ethics procedures are informed by the Health Research Authority (HRA) Research Ethics Service, the Declaration of Helsinki, and the Human Rights Act 1998 (Newcastle University, 2024). The online decision tool deemed the project "low risk" under the premise that all information pertaining to the study was provided and informed, voluntary consent was sought beforehand (Newcastle University, 2024) (see Appendix 5.4). This meant no further review by a Research Ethics Committee (REC) was required.

There were additional approval processes to consider, as participants were likely to work for the NHS. NHS HRA processes vary depending on whether the research involves staff and/or patients and the use of NHS premises and/or facilities (NHS Health Research Authority, 2024). This study involved only staff, and all recruitment and data collection were carried out remotely. The Deep End Network NENC, while including professionals who work for the NHS, is not an NHS organisation. The NHS HRA online decision tool

indicated no additional NHS Research Ethics Committee approval was required (NHS Health Research Authority, 2024) (see Appendix 5.5). This mirrors other Deep End research studies using the same methods and recruitment strategy; namely, Deep End Project: primARy care Professionals' Experience of Reducing opioid and gabapentinoid prescribing in socioeconomically disadvantaged communities in the North East of England (TAPER).

5.2.2. Interview schedule

The interview schedule was designed to last a maximum of one hour and began with introductory and background questions to begin establishing rapport. Information relating to gender or age was not sought from participants as it was not relevant to the research questions. The interview schedule was piloted with a member of the Deep End Network NENC, who provided feedback on the content and my approach as an interviewer. The feedback was positive, but using the interview schedule without disrupting the conversational flow when formatted using questions was difficult. To avoid this in future interviews, they were reformatted as statements. An overview of the interview schedule's key components is presented below:

Introductions (10 mins):

- Consent to record
- Introductions
- Restate ethics
- Any questions?
- Job description (including their link to the childhood vaccination programme).

For local authority and regional-level participants, the following topics were first discussed in general and areas of high socioeconomic deprivation.

Overview – addresses Research Questions 1 and 2 (15 mins):

- Describe childhood vaccination uptake in GP practice/local authority/region.
- Challenges to delivering/commissioning/supporting/monitoring the childhood vaccination programme
- Successes delivering/commissioning/supporting/monitoring the childhood vaccination programme in GP practice/local authority/region.

Specific – addresses research questions one and two (15 mins):

- Describe local patient needs in GP practice/local authority/region.
- Describe difficult-to-navigate policies and/or procedures.
- Describe the data monitoring process and involvement.

Initiatives and interventions – addresses Research Question 3 (10 mins):

General

- Current initiatives/interventions implemented.
- What does work to improve uptake.
- What does NOT work to improve uptake.

Deep End Network NENC childhood immunisation intervention

- Current understanding of the Deep End Network NENC childhood immunisation intervention.
- Opinions on the current format.
- Potential indicators of success.
- Foreseeable implementation issues.

Conclusion (10 mins):

- Important questions/topics not covered.
- Contact details for potential participants.
- Closing remarks.

The statements were adapted to the interviewee's occupational role. For example, “Describe the data monitoring process and involvement” was phrased as “Could you describe the role of data monitoring in your practice?” to GP practice staff, and “Could you describe the role of data monitoring at a commissioning level?” to commissioners. Where appropriate, relevant prompts and follow-up questions were used to probe further into responses.

Specific questions regarding the impact of COVID-19 on the childhood vaccination programme and/or uptake were not directly asked. It was important for this context to arise naturally from the participant. The aim of this thesis was to understand and map the narrative and state of socioeconomic inequalities in vaccination uptake in a post-COVID-

19 era. This suggests provision during the pandemic was not being investigated, but its residual effects.

5.2.3. Transcription, coding and data analysis

The interviews were transcribed verbatim. Zoom and Microsoft Teams' automatic transcription features were used to ease the process. Names and other identifying information were removed, and the transcripts were labelled according to job role. Transcribing as a sole researcher is a lengthy process, but this begins the task of data familiarisation, often cited as one of the most important stages of analysis (Adu, 2019; Braun, 2022; Glaser and Strauss, 2017; Spencer *et al.*, 2014). The transcripts were downloaded into NVivo 14 (Lumivero, 2023) to streamline the analysis. There are several methods of analysing qualitative data, the most common being a thematic approach. The appropriateness of the method depends on the research questions and the format of the collected data (Adu, 2019). This analysis used the framework approach developed by Spencer *et al.* (2014) for large-scale policy research. They define it as:

“...a set of descriptive themes, subdivided by a succession of related subthemes, which are identified through familiarisation with the original material. The framework can be used for indexing but its distinctive feature is that it forms the basis of a series of thematic matrices, in which every participant is allocated a row and each column denotes a separate subtheme. Data are then summarised by case and by subtheme and the summary entered in the appropriate cell.”
(Spencer *et al.*, 2014, p. 195)

The framework generated is both “grounded” and “dynamic”, meaning it is rooted in the original accounts and open to change throughout the analysis (Spencer *et al.*, 2014). Gale *et al.* (2013) suggest this method is appropriate when the researcher requires individual accounts to be easily identifiable. This interview study sought the differing opinions of professionals from across the childhood vaccination process. As the findings can be segmented according to job role, taking a framework approach meant one analysis could be performed. The framework is presented as a matrix-style table, as illustrated in Table 5.1.

Table 5.1

An example of a matrix-style table used in framework analysis.

	Initial Theme 1	Initial Theme 2	...
Transcript 1	Codes: A.1, A.2, A.3 - Summarise the contents of transcript 1 relevant to initial Theme 1. “relevant quote/s”	Codes B.1, B.2, B.3 - Summarise the contents of transcript 1 relevant to initial Theme 2. “relevant quote/s”	
Transcript 2	Codes: A.1, A.2, A.3 - Summarise the contents of transcript 2 relevant to initial Theme 1. “relevant quote/s”	The cell remains blank if the transcript does not refer to the theme.	
...			

There are shortfalls in a framework approach to analysis. Firstly, it aims to capture all data systematically, which can be time-consuming and labour-intensive (Gale *et al.*, 2013). Secondly, due to its structured approach, it could be argued it is incompatible with the qualitative paradigm (for more information on research paradigms, refer to Section 3.4.1, *Epistemology and ontology*). However, the creative processes commonly associated with qualitative analyses still drive the theme creation in a framework approach; it is more of a form of data management (Spencer *et al.*, 2014).

Gale *et al.*'s (2013) seven-step process for conducting framework analysis in multi-disciplinary health research was used as a practical guide. The process is outlined in Table 5.2.

Table 5.2

A table describing Gale *et al.*'s (2013) seven-step process for performing a framework analysis and the relevant thesis sections.

	Stages	Description	Relevant thesis section
1	Transcription	Verbatim, but not all dialogue conventions are required – it is the content that matters. Begins the process of familiarisation.	5.2.3, <i>Transcription, coding and data analysis</i>
2	Familiarisation of the interview	Using interview recordings, transcripts, and/or fieldwork notes. Identify initial impressions.	
3	Coding	Read transcripts line by line, applying paraphrase or label (a code). Codes can be applied to everything and arise from the data (open coding) or can be specific and pre-	

		defined. A portion of the transcripts should be corroborated with another individual.	
4	Developing a working analytical framework	The codes are grouped into categories, which are then defined, sometimes referred to as “themes”. This becomes the working framework and will likely experience many iterations.	5.3.2, <i>Theme overview</i>
5	Applying the analytical framework	Each transcript is indexed using an identifying number or abbreviation for codes. Computer software can make this process easier.	
6	Charting data into the framework matrix	A spreadsheet matrix is generated, where each row represents a transcript and each column a category. For each participant, their discussion of the category is summarised using stand-out quotes.	
7	Interpreting the data	Identifying characteristics and differences and mapping connections across accounts.	5.3.3 to 5.3.7

The analysis fluctuated between stages three and four before moving to stage five. Saldana (2021) refers to this as “coding cycles”. The analysis employed structural coding, utilising content-based or conceptual phrases related to the research questions. Structural coding aligns with a framework approach to analysis, as it is useful for exploratory investigations (Saldaña, 2021), like this study.

To ensure the coding and theme formation processes were logical and appropriate, an independent researcher (TP) was sought as a secondary rater. TP has extensive qualitative analysis skills and experience applying the framework approach to vaccination uptake studies (Price, McColl and Visram, 2022). They independently coded one anonymised transcript, which was then compared to mine. There was a high degree of inter-rater consistency, with TP and I identifying similar codes and agreeing on the subsequent theme development.

5.3. Findings

5.3.1. Overview of data collection and participant information

Fifteen interviews were conducted between June 2023 and December 2023. The Deep End Network NENC childhood immunisation intervention was rolled out to interested practices on 29th January 2024, meaning data collection had concluded. Any reference to

the intervention was from a pre-implementation perspective. There were no participant dropouts, although the response rate was low, and one participant declined due to work pressures.

Participants were recruited using different strategies:

- Direct contact using participants' professional email addresses and my university email address (n = 6).
- Using GP practices email addresses and my university email address (n = 2).
- Using the Deep End Network NENC mailing list and official email address (n = 4).
- Snowball sampling – interviewees provided the contact details of other potential participants (n = 3).

Two interviews had to be rescheduled due to technological issues. The participant details are presented in Table 5.3. The “dual roles” category meant interviewees were involved in the in-practice delivery of the childhood programme as well as occupying a leadership role in the wider vaccination system. The interview schedule was designed to last a maximum of one hour; fourteen were completed in 40 to 55 minutes, with one lasting over one hour. The interview guide was successful. Many topics, such as those related to the role of data and data management, did not require asking directly because interviewees referred to them unprompted. Interviewees also reflected on the impact of COVID-19 without being asked, as hoped.

Transcription and coding were performed in the days following the interview. After the first 13 interviews, all major actors in the childhood vaccination process (nurses, GPs, practice managers, commissioners, public health employees, and healthcare delivery partners) were accounted for, and the number of newly generated codes significantly decreased. Two more interviews were sought: one from a Local Authority Public Health employee to provide opinion diversity for this professional role and one from a specific commissioner mentioned throughout the interviews as vital to the childhood vaccination system. Thus, data collection ceased at 15 interviews.

Table 5.3

A table outlining the fifteen interview participants, including their anonymised labels and occupational details.

Participant Details	Geographical location	Occupation Details
Deep End GP practice employees (n = 5) <i>(deliver the childhood vaccination programme)</i>		
Nurse 1	Newcastle	Nurse practitioner
Nurse 2	Newcastle	
GP 1	Sunderland	GP and practice partner
Practice Manager 1	Middlesborough	Practice manager.
Practice Manager 2	South Shields	
Dual roles (n = 3) <i>(deliver and support the childhood vaccination programme)</i>		
GP 2	Gateshead	GP, practice partner, and role in the leadership of external healthcare organisation.
GP 3	Sunderland	
GP 4	Durham	
Professionals involved in the wider childhood vaccination system (n = 7) <i>(commission, support, and monitor the childhood vaccination programme)</i>		
Commissioner 1	North East and Yorkshire	NHS England North East and Yorkshire
Commissioner 2		
Commissioner 3		
Commissioner 4		
Healthcare Delivery Partner 1	North East and Yorkshire	A private organisation that supports healthcare delivery.
Public Health Employee 1	Middlesborough	Local authority public health team.
Public Health Employee 2	Hartlepool	

Interviews n = 15

5.3.2. Theme overview

Five themes emerged from the analysis, as depicted in Figure 5.1 and outlined below:

Theme 1 – The North East paradox: exploring childhood vaccination uptake in the North East of England.

Theme 1 is contextual, exploring opinions on childhood vaccination uptake levels in the North East of England. It acknowledges that, while uptake is comparatively higher than in other regions, there are pockets of low uptake. It explores whether this is linked to socioeconomic deprivation or the lingering effects of the COVID-19 pandemic.

Theme 2 – From policy to practice: the childhood vaccination system and data flows.

Theme 2 describes the childhood vaccination system from a top-down perspective. It focuses on the transmission of national policy via regional commissioning teams to service providers. Also, it reflects on the implementation of this process in Deep End NENC GP practices.

Theme 3 – Vaccinating the minority: the challenges of delivering the childhood vaccination programme to families from underserved communities.

Most children are vaccinated in the recommended timeframe with minimal intervention on behalf of their GP practice. For the minority, however, more input is required. This is especially the case for children from underserved communities, of which there is a high prevalence registered at Deep End NENC GP practices. Theme 3 explores both practical challenges experienced by providers and their opinions on parental barriers to appointment attendance.

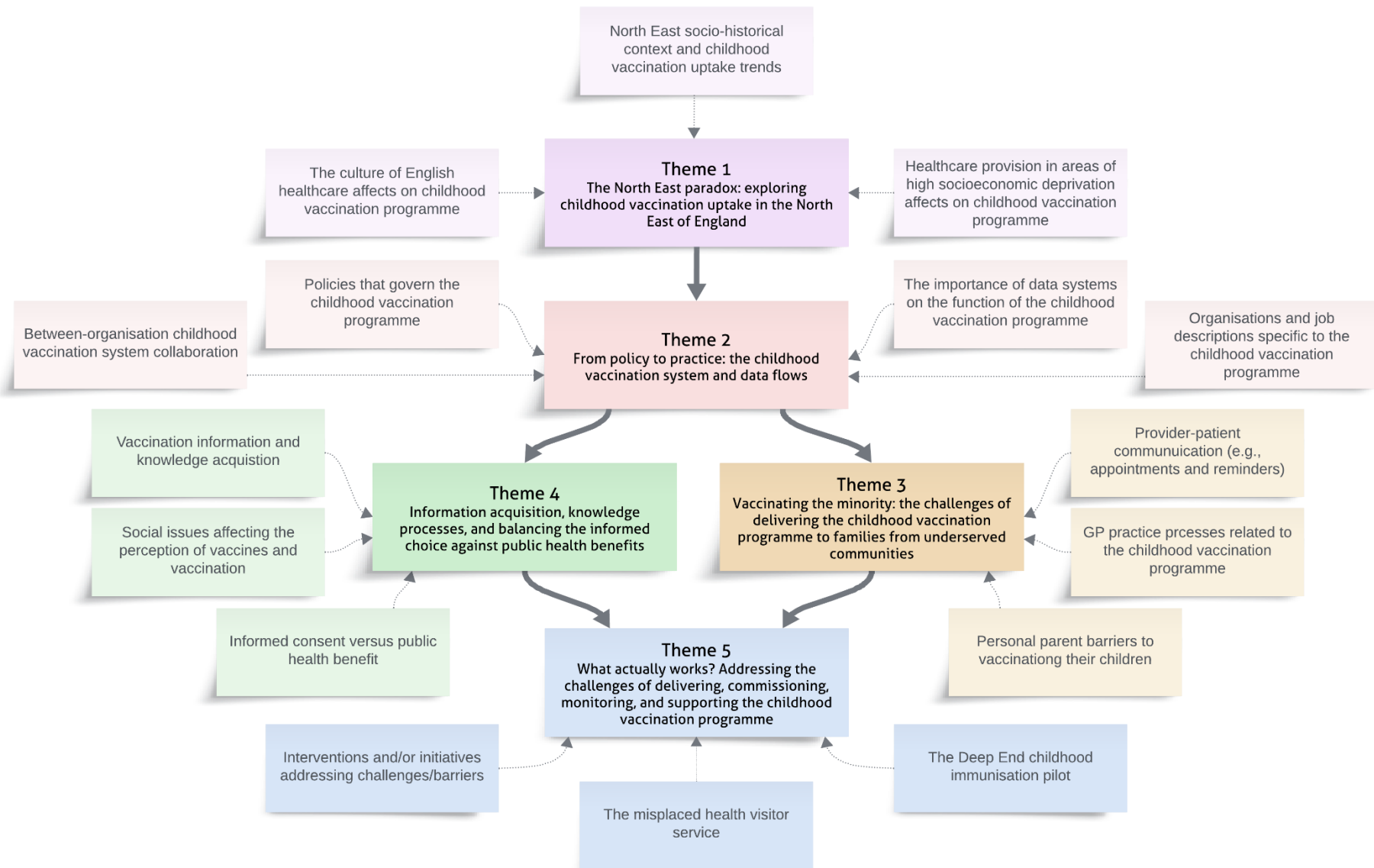
Theme 4 – Information acquisition, knowledge processes, and balancing informed choice against public health benefits.

Theme 4 describes the importance of parental education and health literacy, including vaccine and vaccination-specific knowledge, and some social issues that have affected the perception of vaccines and vaccination. It discusses balancing individual and public health benefits in a society that supports informed vaccination personal decision-making.

Theme 5 – What actually works? Addressing the challenges of delivering, commissioning, monitoring, and supporting the childhood vaccination programme.

Theme 5 analyses some initiatives and interventions aimed at improving or supporting the childhood vaccination programme, including a pilot organised by the Deep End Network NENC. This theme captures the conflicting perspectives on the best means of increasing uptake and suggests that already established mechanisms, such as Health Visitor service, may be most effective.

Figure 5.1 Overview of themes and their relationship to one another.



5.3.3. Theme 1 – The North East paradox: exploring childhood vaccination uptake in the North East of England

Theme 1 is contextual, exploring opinions on childhood vaccination uptake levels in the North East of England. It acknowledges that, while uptake is comparatively higher than in other regions, there are pockets of low uptake. It explores whether this is linked to socioeconomic deprivation or the lingering effects of the COVID-19 pandemic.

Uptake in the North East outperforms any other region in England for most childhood vaccines, a label considered “*remarkable*” [Healthcare Delivery Partner 1]. Reportedly, this is a historical trend.

“We've actually been like this in the North East for many years...been either at or near the top of the coverage rates in the country.” [Commissioner 3]

Interviewees suggested many theories for this trend. However, Commissioner 2 and Healthcare Delivery Partner 1 were keen to enforce that these suggestions were based on their personal opinions and experiences, not statistical evidence. There is potentially more stability in the North East than in other regions, which allegedly impacts three factors related to childhood vaccination uptake: ability to foster a greater sense of community, more consistent local healthcare services, and easier uptake monitoring. Often, participants used comparisons to other regions to articulate their argument, such as areas with (comparatively) more mobile populations. For communities, it promotes “*next-door neighbour knowledge*” [Commissioner 1] that can encourage parents to vaccinate their children.

“[mimicking North East parent] ‘Eee, my sister had measles, and it was awful. You want to get them jabbed!’” [Commissioner 1]

Subsequently, this perpetuates the idea that vaccinating your child is a social norm, meaning the decision to vaccinate is not questioned.

“I don’t know whether or not it’s a cultural thing, that there is just a history of you get your jabs...” [Delivery Partner A]

For local healthcare services, stability means trusting relationships between patients and providers are more easily built. The importance of these trusting relationships in the context of vaccination is further explored in Theme 3. Across England, there has been an absolute decline in patient-provider relations. Often, families do not have a named GP,

which decreases the continuity of care. Commissioners in the North East felt that this affected their region less. Additionally, it is easier in less mobile populations from a data monitoring perspective to ensure that child health records are current. Transferring child health records to another Child Health Information Service (CHIS) team is not always seamless due to different operating systems.

“...we probably do have a more stable primary care, and maybe even better resourced primary care system. And, although I would have to do some work to evidence that well, I think that's just through general observation that people do tend to stay around for quite a long time in the same place, in healthcare jobs of one sort or another.” [Commissioner 3]

“...it's also quite a stable population; if you look at somewhere like London, they've got a huge amount of movement of population, and that can't be easy in terms of those very fundamental measures of having a consistent, trusted relationship between primary care and population, and just keeping records straight, making sure that those records follow the people...” [Commissioner 3]

Moreover, some groups may face more “barriers” [Healthcare Delivery Partner 1] when accessing childhood vaccination services than other populations. These barriers are further explored in Theme 3. Still, this discussion is related to the second alleged reason for the North East’s high uptake levels: the lack of ethnic diversity compared to other regions in England (see Section 5.1.2, *The North East of England: a brief history*, for more information).

“...we are the least ethnically diverse part of England. We know the uptake is lower in minority and ethnic groups...” [Healthcare Delivery Partner 1]

“I personally think that there's something to do with the diversity and ethnic mix within the population...” [Commissioner 3]

Healthcare Delivery Partner 1 and the commissioners who commented on this topic suggested that the current healthcare system underserves these communities because their adverse experiences are not adequately addressed. Theme 3 discusses what is meant by “ethnic diversity” and how using this as a blanket term does not reflect the underlying causal mechanisms – E.g., language barriers and differing cultural perceptions of vaccination.

Participants reported an increase in cultural diversity in the North East in recent years. There were concerns that the healthcare system was unprepared to serve diverse

populations adequately. For instance, vaccination information may not be available in a parent's first language, making it inaccessible.

"It's whether or not we have rested on our laurels because we've had such high uptake that, actually, we haven't adapted our delivery to meet the changing demographic. That would be a failing on healthcare services, to not engage communities in culturally sensitive and competent ways." [Healthcare Delivery Partner 1]

On the other hand, while proud of their high uptake levels, some commissioners argued that this discourse does not necessarily reflect the situation at a more granular level. They suggested there are pockets of low uptake that are not visible from an aggregate perspective.

"Although our area has very good uptake rates, as compared to the rest of England, when you drill down to GP level data you can see there is geographical variation." [Commissioner 2]

"I think that what happens with the 'we get good rates', is that you actually miss out pockets of the population; you don't look hard enough." [Commissioner 1]

Public Health Employee 2 reported that measles outbreaks historically occurred in areas with low uptake of the second MMR vaccine (MMR2). Unvaccinated children may be clustered in schools or communities, making the areas more susceptible to outbreaks.

"We've got some schools where there's only one child in that whole school that hasn't had both doses of their MMR, then we've got other schools where there's 28% of them which haven't had both doses" [Public Health Employee 1]

This further supports the importance of exploring the distribution of uptake as well as overall coverage. Newcastle City and Middlesbrough were referenced as two of these low-uptake areas. The reasoning for these compliments the theories of why the North East outperforms all other regions, as Newcastle and Middlesbrough are reported to have high levels of mobile communities and ethnic diversity.

"There's a lot of mobile communities and ethnic groups within Newcastle, similarly within Middlesbrough, so those are the areas that we struggle with uptake particularly." [Commissioner 2]

Some participants attributed the lower uptake levels in Middlesbrough to being an area of high socioeconomic deprivation. However, it was also recognised that less deprived areas also exhibited lower levels of uptake, especially for the MMR vaccine.

"I think Middlesbrough is one of our most deprived, I think it's the most deprived local authority in the country, so that may have something to do with it. Having said that, we don't really have a large body of evidence that directly links deprivation

with poor uptake in childhood imms in particular. We looked at MMR, and actually it didn't prove that at all. There are some areas that are really quite affluent who have low uptake, and vice versa.” [Commissioner 2]

There were three suggested reasons for lower uptake amongst advantaged socioeconomic groups: (1) working mothers' difficulty attending vaccination appointments, (2) a potential lack of familial support due to moving for work (another example of greater difficulties experienced by mobile individuals), and (3) substance misuse. Reportedly, advantaged socioeconomic groups have more money to spend on substance abuse, meaning the child's “*health needs [are] not getting met*” [Public Health Employee 2], including vaccination.

“It would be those parents who are back at work, both working in 9-5 and that ability to get their child in for an appointment...trying to juggle work to get to an appointment, and cover, it is quite difficult...some families live in areas where they've moved for work and maybe don't have that family support to help around children coming in.” [Public Health Employee 2]

However, these challenges are not unique to this group. Individuals experiencing socioeconomic disadvantage also experience these (further explored in Theme 3).

Some participants working in Deep End GP practices insisted their uptake levels were not low. This was supported by the wider vaccination system professionals (commissioners, local authority employees, and healthcare delivery partners) who were familiar with the Deep End Network. However, it was accepted that Deep End GP practices had to invest more staff time and effort into meeting vaccination uptake targets than practices in less deprived areas.

“Not all the Deep End practices have poor uptake, a lot of them had really good ones. However, what was clear was what they were having to do to secure those, was over and above.” [Commissioner 1]

This demonstrates the importance of qualitative investigations. Two practices with the same level of uptake may have different experiences of delivering the childhood vaccination programme. For one, targets may be met with relatively minimal practice intervention, whereas another may require several instances of call and recall. The latter practice may be at a greater risk of fluctuations in uptake due to this. “Call and recall” is the official process whereby patients are invited to a healthcare intervention.

Overall, however, the North East has seen the same recent decline in childhood vaccination uptake as all other regions across England. It was suggested that COVID-19 may have played a role in this.

“...I think you've got two distinct pictures, pre-COVID and post-COVID. Pre-COVID, if you look at COVER, which is the main one that people look at, you've got relatively good rates in the North East, certainly better than other parts of the country. If you look post-COVID, it's starting to become clearer that that perhaps isn't the case. We're seeing the same gradual reduction in uptakes that they've seen across the rest of the country...” [Commissioner 1]

This was associated with an “*absolute reduction*” [Commissioner 1] in services, which has exacerbated the increasing pressure placed on GP practices and, by extension, the childhood vaccination programme. This contributes to further difficulties in the availability of convenient appointments (explored in Theme 3). The pandemic also affected families, such as being increasingly “*vulnerably housed*” [Commissioner 1]. Vulnerable housing may mean families have to relocate more frequently, which, as explored, decreases stability and is linked to lower uptake. They may move outside their GP practice’s catchment area and must re-register elsewhere, which could interrupt timely vaccination.

5.3.4. Theme 2 – From policy to practice: the childhood vaccination system and data flows

Theme 2 describes the childhood vaccination system from a top-down perspective. It focuses on the transmission of national policy via regional commissioning teams to service providers. Also, it reflects on the implementation of this process in Deep End NENC GP practices.

The NHS England Public Health Programmes (NHSE PHP) Team North East and Yorkshire commissions all Section 7a Public Health Functions for the area (for more information, refer to Section 3.2.1, *The English healthcare system*). They act as a “*system voice*” [Commissioner 3] by overseeing the implementation of national policy at a regional level. Several NHSE PHP team members have occupational backgrounds in provision, such as nurse practitioners or health visitors, which is deeply valued. This ensures they are not “*sitting in their ivory tower*” [Commissioner 3], lacking an understanding of how the

childhood vaccination programme is delivered in GP practices. This demonstrates the importance of a consistent dialogue between policy and practice.

"It's important to have those kinds of people at our level in the system. If we were all just the contracting and administrator kind of people, we probably would be missing the point in quite a lot of ways." [Commissioner 3]

"We're a commissioning team with a really limited budget, and I've been in practice long enough to know that somebody coming along going 'what do you need?' has just wasted my time if they don't actually provide me with anything I need. But somebody coming along saying, 'we've got no money, but what can we do, practically, from the networks we do have'." [Commissioner 1]

Although these reflections were made by commissioners and may present a favourable perspective. The use of behavioural insights work by commissioners and local authority public health employees was mentioned. They spoke to GP practice staff, to discuss the challenges of delivering the childhood vaccination programme, and parents, to identify barriers to access. This is further discussed in Theme 5 but is an example of professionals in the wider vaccination system grounding their approach in primary, empirical data.

However, one interviewee felt the dialogue between the wider healthcare system and providers was lacking. In reference to low uptake, Practice Manager 1 claimed

"They have no understanding of that, public health, ICB, they don't have any understanding, they have no idea, they just think we're not inviting them [children for vaccinations], I'm sure that's what they think!"

However, the opposite was reported. It was recognised that Deep End GP practices were *"working above and beyond the spec"* [Commissioner 1], and the high levels of uptake in the North East is a *"testament to primary care"* [Healthcare Delivery Partner 1]. The discrepancy between these perspectives could mean the current frequency or nature of dialogue may not be adequate. One commissioner agreed with this.

"We have done various surveys to get the field to tell us like how things work, or don't work. But, should we be doing more of that? And the answer, it probably is, yes, I would say." [Commissioner 3]

The childhood vaccination programme is commissioned through the GP contract, *"a huge and complicated contract, paying for all of the activity that GPs do"* [Commissioner 3] (for more information, refer to Section 3.2.1, *The English healthcare system*). GP practices are, fundamentally, individual businesses, meaning they can interpret and

implement the GP contract differently. This can make it difficult for commissioners to ascertain whether they perform according to specifications. Thus, steps have been taken to provide more standardisation and guidance for GP practices.

“There was no national standardised pathway for routine immunisations for 0-5s, and we had no way of knowing what their call and recall was, what their procedures were, were they following best practice guidance? And so, we mapped out from a child being born, right through to the final set of imms, we mapped out the routine pathway and put it as a graph thing. Then, each section of the pathway, we took all the best-practice guidance that was available.” [Commissioner 2]

It was suggested in Theme 1 that both qualitative and quantitative forms of data are required to portray the reality behind the statistics. Subsequently, there must be constant, accurate, and timely data flows to the appropriate stakeholders to enable this system to function. NHSE commission Child Health Information Services (CHIS), which is described as the “hub” [Commissioner 4] of data. CHIS consist of three components: an “electronic system that’ll store all this [data]...a workforce, and links to the Red Book.” [Commissioner 4].

The North East has seven CHISs (for more information, refer to Section 3.2.1, *The English healthcare system*). One of their functions is to ensure uptake statistics are accurate before submission to Cover of Children Evaluated Rapidly (COVER) for publication (refer to Section 4.2.1, *Vaccination uptake data*, for more information). Commissioners believed these rigorous data-verifying procedures are another reason for the appearance of high uptake levels in the North East, as explored in Theme 1. However, comparisons with data-verifying procedures in other regions must be investigated to validate this theory.

“We’ve managed to keep some good pretty good consistency in terms of tight data systems, and some of that is just through pure, long term, very diligent, relationships between particularly the child health information teams and the individual GP Practices; constant checking and chasing about details and making sure that the data is correct.” [Commissioner 3]

The above quote demonstrates the importance of CHIS-GP practice relationships. The two public health professionals interviewed expressed their “biggest ask” [Public Health Employee 1] is to be more integrated into these data flows. They receive the data after a delay, meaning they cannot monitor the risk of disease outbreaks in their population.

“We were like, ‘Oh my God, we might be at risk of an outbreak here, and we’re just finding out!’” [Public Health Employee 2]

However, it was recognised that there may be data-sharing issues with this, but the benefits, nevertheless, would outweigh the logistical considerations.

As GP practices are permitted to implement the childhood vaccination programme differently, each CHIS is permitted to choose its administrative operating system and staffing structure.

“...it's difficult because you've got different systems...from an NHSE point of view, it's like open market, free market, you can't say which system you have to use...they have to meet certain technical requirements, and we don't say about staff as well either, so however they want to run it, and you'll find CHISs have various different staffing levels within the ones that we have...” [Commissioner 4]

Thus, they can have differing levels of engagement with practices and, sometimes, parents; *“It depends on what part of the region you're in as to how far they go”* [Commissioner 3]. Two practices reported receiving lists of unimmunised children from their local authority or CHIS. This was discussed favourably because practices did not have to do this themselves. However, occasionally, there are discrepancies between the GP practice and CHIS vaccination uptake data.

“We get a list every week from our local authority, and it tells us which children are due which immunisations.” [Nurse 1]

“...Child Health Services tells us who needs to be immunised...” [Practice Manager 2]

The non-standardised approach has both strengths and weaknesses. It allows each GP practice and CHIS to provide a service best suited to the populations they serve. From a commissioning perspective, however, it creates tension with oversight. Equally, local authority public health teams have different processes and procedures. These differences can create dysfunction within the system. For instance, some practices rely on administrative operating systems that require manual data transference, whereas others use systems where this is computerised. This exposes the process to possible data discrepancies.

A balance between acknowledging the free-market principles and delivering a streamlined service performing to specification is required. GP practice employees reported the challenges of finding the correct balance between the needs of a business (E.g., income and profit) and meeting the healthcare needs of their patient population.

The Quality Outcome Framework (QOF) attempts to do this, but interview participants across the vaccination process felt the balance was incorrect in its current form. There are QOF targets for several GP practice services (E.g., Asthma and Diabetes reviews and cervical screening), which financially reward practices based on how many points are achieved. For childhood vaccination, this refers to the proportion of eligible children vaccinated in a specified timeframe (refer to Section 3.2.1, *The English healthcare system*, for more information).

Providers felt that QOF targets were set too high. Subsequently, they do not incentivise and may have the opposite effect.

"There is a potential, perverse disincentive...if I was running it purely as a business, I would say, 'Right, I'm going to divert that nursing, admin, clinician time. So we'll just stop doing that, and we'll focus on the targets that we can get'. Of course, you wouldn't do that because you're not protecting your patients that way. If it was a purely business transaction, why would you put a lot of time, staff and investment into a target you can never hit? It's a ludicrous premise, in my opinion."
[GP 3]

"...if you know the best you're ever going to get is 60%, but the target is set at 80%, well why are we bothering to try and get 60%, because we're not going to get anything for that, so you don't put effort in...because it's not going to help anybody. Well, it'll help the patients, but unfortunately, because it's all now financially driven..." [GP 4]

Multiple participants expressed frustration with QOF targets and their counterproductive nature. If practices do not receive the payment, this can make the targets more difficult to achieve in future.

"If you take funding away, you're taking hours away, you're taking admin away. You can only do what you can do within the resources that you have available."
[Practice Manager 1].

Providers felt the "perverse disincentive" of QOF adversely affects Deep End GP practices.

"...practices that work in the Deep End...have a challenge in meeting their QOF targets...what that then results in is lower income for practices who already have lower income." [Delivery Partner A]

"To get my immunisation targets, as I described earlier, it takes a lot more effort than in the kind of practice where everybody just turns up and gets their jabs." [GP 3]

Commissioners acknowledged that, currently, QOF payments were not appropriately incentivising GP practices to reach their childhood vaccination uptake targets.

“On the one hand, I think that the item of service is good because, by definition, the more a GP [practice] does, the more they will get paid and, therefore, there is some financial incentive. The actual amounts for the extra effort involved might not really justify the extra work.” [Commissioner 3]

Despite acknowledging their shortfalls, Commissioner 3 utilises the term *“incentive”* when referring to QOF, whereas GP 3 labels them a *“perverse disincentive”*. There is a direct contrast between these two perspectives. This is an example of where policy, in reality, may not manifest as expected. Whilst commissioners are aware of these shortfalls, they argue that changing the GP contract *“takes time”* [Commissioner 3]. However, one example where the regional NHSE team used their *“system voice”* [Commissioner 3] to spearhead change was the recording of uptake for children who began their vaccination schedule outside the UK. There was no means of identifying this in the system, and the child may have been registered at the practice outside the timeframe for QOF.

“It makes it look as though those people haven't been vaccinated and then the practice gets unfairly penalised for that, financially, but that isn't the case, the child is exactly where they should be; they've got the schedule that they should have for the person, but the system can't pick it up, and then that child goes into the data and corrupts all the data...That's one that we've raised with the national team, and they've actually changed now how you can record it” [Commissioner 1]

Deep End GP practice employees felt they had a (relatively) lower income than practices in more affluent areas because the Carr-Hill formula used to calculate income is not fit for purpose. The Carr-Hill formula is based on patient list size and demographics, including level of socioeconomic deprivation and prevalence of elderly individuals (refer to Section 3.2.1, *The English healthcare system*, for more information). However, it does not account for situations where there is a greater prevalence of younger ill-health. This is reportedly the case in Deep End GP practices, and the adjustment for socioeconomic deprivation is insufficient.

“I don't think the Carr-Hill formula is fit because it doesn't account for the fact that you might have a working-age adult population who've got quite a lot of comorbidity and therefore requiring quite a lot of health input.” [GP 2]

While these issues are not confined to the childhood vaccination programme, they are important to overall funding.

"I think the main thing I would say is that in a Deep End practice, you need more of every staff group to try and deliver the same outcomes in a less deprived area."
[GP 1]

However, one participant felt the debates about QOF and practice income were *"missing the point"* [Practice Manager 2].

"It's bigger than money and points, these children need to be vaccinated."
[Practice Manager 2]

"QOF is important, but patients first." [Practice Manager 2]

These quotes refocus the discussion on the children who require protection against harmful vaccine-preventable diseases. Finances are important to ensure the vaccination programme can be provided according to specifications. Still, it is easy to become entangled in debates about policy and practice and forget the bottom line.

5.3.5. Theme 3 – Vaccinating the minority: the challenges of delivering the childhood vaccination programme to families from underserved communities

Most children are vaccinated in the recommended timeframe with minimal intervention on behalf of their GP practice. For the minority, however, more input is required. This is especially the case for children from underserved communities, of which there is a high prevalence registered at Deep End NENC GP practices. Theme 3 explores both the practical challenges experienced by providers and their opinions on parental barriers to appointment attendance.

This theme is concerned with practical challenges to vaccination. Instead of using the term "uptake", "appointment attendance" is employed because the former implies issues with the practice of vaccination, which is explored in Theme 4. There were conflicting opinions on the most successful method of communicating with parents about vaccination. One GP felt they had more success with attendance when administrative staff booked the appointments and contacted parents with the details. They admitted this was a *"doctor-centric"* [GP 1] approach, but one that worked for their practice as parents reportedly had *"low patient-activation, specifically for immunisations"* [GP 1].

“What we do is we send them an appointment and say, this is your appointment, come. And actually, that gets a reasonable amount of people, cause actually they've got a reasonable ability to turn up to an appointment if they're told when to come. But the minute you make them contact, almost impossible.” [GP 1]

Others said their practice encouraged parents to book vaccination appointments by telephone or via hyperlink sent in an SMS message. These are both more patient-centred approaches to appointment communication.

“Instead of ringing them, I'll write to them. We send them a link, and we have so many appointments that they can book into so that they've got plenty of choice, they can book themselves.” [Practice Manager 2]

“We contact them and say, ‘Your child is due these immunisations, please make an appointment with the GP surgery.’” [Nurse 1]

The success of the online booking system was unknown at the time of the interviews, as it was a recent implementation. However, Practice Manager 2 reported their initial observation was that it only benefited parents who would have organised and attended their child's vaccination appointment regardless. It appeared not to have benefited those who were *“harder to reach”* [Practice Manager 2].

GP 1 suggested they used online booking for other vaccination appointments, such as influenza, but not the childhood programme, because *“the schedule is often a schedule for a reason, and you've got to be within the right window”* [GP 1]. This is in reference to the QOF targets discussed in Theme 2. With no definitive suggestions as to which method works best, this demonstrates the unique healthcare needs of patients; *“one size can't, and shouldn't, fit all”* [Commissioner 3]. It also relates to the importance of balance explored in Theme 2. Standardisation of care is required to provide equal service, but this may underserve some patients (refer to Section 1.2.1, *The Socio-ecological Model of Health and health(care) inequalities*).

Practices offer appointment flexibility, a feature Commissioner 3 reports is part of the GP contract. However, flexibility may differ across practices, such as not operating a vaccination clinic model. Clinic models are when a particular service is only available on a specified day and/or time. This can restrict the availability of appointments.

“[Discussing what works to improve appointment attendance]...not having a dedicated clinic so you're restricting the day and the time, whereas ours can book in any time that we've got a nurse in...” [Practice Manager 1]

“When I came, they said, ‘That’s our baby [vaccination] clinic’ I said, ‘No, no, every day is a baby clinic!’” [Practice Manager 2]

GP practice interviewees reported the utilisation of opportunistic appointment booking as an important initiative. Opportunistic appointment booking is where the parent of an unvaccinated child is attending, or in contact with, the GP practice for another reason, and the interaction is used to book an appointment.

“When our children come in for their first checks, they have an appointment with us, and they have an appointment with the GP. And while they’re here, we make the next appointment, and then when they come for the next appointment, we make the next appointment...” [Nurse 2]

GP 1 reported they would like to implement the approach outlined above in their practice as they experience a “drop off” [GP 1] in attendance when the first vaccinations are scheduled for the week following newborn check-ups with a GP. The approach of Nurse 2’s practice reduces the occasions parents must contact the practice to arrange an appointment and attend the practice for said appointments.

This demonstrates the importance of how and when the vaccination offer is communicated to parents. It appears to suggest a flexible and opportunistic approach is most successful. Online booking systems may help reduce staff time spent on booking appointments. Even if this does not benefit underserved communities, it frees administrative time to focus on these families. However, in the instance of opportunistic appointment booking, it was reported that these unvaccinated children first need to be identified, which can represent a significant task. Some practice managers are involved in this process, demonstrating that childhood vaccination is a whole-practice responsibility.

“Our operations manager for the practice will go through the appointments, and if there’s any children who are due vaccinations and they’re coming in for another reason, we’ll put a comment alongside the patient’s appointment for the admin staff that they need to be booked in for their childhood immunisation.” [GP 2]

The second facet of Theme 3 explores the types of families which providers report are more difficult to vaccinate, as they may face more barriers to uptake. The first group were those from “chaotic families” or “patients with chaotic lives” which twelve of the fifteen participants referred to.

“...immunisations are always more difficult in populations who find it hard to bring organisation into quite chaotic lives...because crises happen regularly in their lives and that takes precedence over a planned attendance.” [GP 3]

Interviewees conceptualised “*chaotic families*” differently, but the term was often used in a safeguarding context.

“Usually it relates to alcohol, drugs, police involvement, crime...or domestic violence in the home...these families frequently have safeguarding or child protection issues, are children-in-need, or are looked-after children.” [Nurse 1]

However, drug issues were reported as a reason for low uptake in both advantaged socioeconomic settings, as explored in Theme 1. Nevertheless, Theme 3 identifies this as an issue in Deep End GP practices, thus supporting the idea that it is not confined to one socioeconomic group.

Some participants questioned the term “*chaotic families*” to describe this group. It has undertones of blame and contempt regarding families with complex personal lives.

“The term chaotic families or families hard to reach [is] just blaming those families when maybe we could be more person-centred in our approach to healthcare delivery.” [Public Health Employee 2]

As a consequence of the difficulties these families are experiencing, they often have an incompatibility with planned healthcare and thus struggle with scheduling and attending their child's vaccination appointments.

“...I don't think it'll be her priority to say, ‘In 8 weeks, I'm going to come in. Have I got that appointment? Is my red book ready?’ And all the things that probably, if you're a middle-class person who your health and your baby's health is really on your mind all of the time, everything's meticulous...” [GP 2]

“...there's something about planned care that some of our patients just cannot manage.” [GP 2]

The above quote suggests that middle-class families have a more thorough approach to their child's healthcare than those registered at Deep End GP practices. Statements such as these may contribute to a blame culture surrounding disadvantaged socioeconomic groups. GP 4 takes a different approach to this subject:

“...coming back to Maslow's Hierarchy, if you've not got the basis of the warm house or roof over your head, you've not got food on the table, then vaccination is not going to be a priority.” [GP 4]

Maslow's Hierarchy of Needs (1943) suggests five categories of human needs: physiological needs, safety and security, love and belonging, self-esteem, and self-

actualisation. When considering this, there are many reasons parents may feel unable to attend the GP practice for their child's vaccinations. GP 4 suggested that "*pride*" prevents families from seeking help. In the above quotes, GP 2 and GP 4 use the term "*priority*" when referring to the parents' view of vaccinating their children. Thus, parents do not possess negative opinions about vaccination, but other issues are more imminent and concerning.

"..it's not even probably about choosing to have them and not choosing not to have them, just never getting around to it because there's so much else going on in their life that they're preoccupied by." [Public Health Employee 1]

"...I don't know this for sure, but you might find you'll have parents who are not vaccinating their children, not because they don't believe in vaccinations, not because they've got a big, strong opinion about vaccinations, but maybe just because they can't get there..." [GP 2]

Discussions of the priority of vaccination link to incompatibility with planned healthcare and the need for appointment flexibility. Families whose lives are categorised by instability may be better served using a drop-in model where appointments are not required, as hypothesised by one participant.

"[Discussing a drop-in childhood vaccination model]...they might use it because they might think, 'Do you know what, I'm going to go there because I don't need an appointment. I can go, get the injections, and come away.' I don't know, I think something like that might work..." [Nurse 1]

One participant felt it important to emphasise that low appointment attendance may result from a lack of parental motivation.

"In all honesty, and I know it sounds harsh, Amber, but many people just can't be arsed. I know that sounds awful, but it is true." [Commissioner 2]

This adds some balance to the debate that whilst these barriers and challenges are real, they may not be applicable to every family, parent, and child.

Parents who face more barriers when accessing vaccination services are more likely to "*DNA*" [Practice Manager 2] – did not attend. However, DNA's are not confined to the childhood vaccination programme.

"[Discussing challenges of delivering the childhood vaccination programme]...non-attendance for planned care in every process, and immunisation is just another facet." [GP 3]

As discussed in Theme 2, this enforces that the childhood programme is only one feature of the GP contract, and many issues are experienced for other services. Participants reported feeling powerless against DNA's.

"...even if we book an appointment, they might not turn up, then there's re-booking of that. That's 20 to 30 min slot wasted for a nurse, and then obviously, we have to catch-up and try and call and recall them again..." [GP 2]

A practice manager claimed they have recently implemented a procedure where the parents who have DNA'd are contacted by a nurse during the missed appointment. This means staff time is not wasted, and

"...it doesn't take long to make that telephone call, they're done in, average, 7 minutes. The appointment's 20." [Practice Manager 1]

The practice manager felt this did not increase nurses' workload; it just *"changed the nature of the work"* [Practice Manager 1].

This approach to dealing with DNAs may be additionally beneficial, considering parents are reportedly more receptive to a clinician (GP or nurse) following up on their non-attendance and encouraging uptake rather than a non-clinician (administrator).

*"When a non-clinical person contacts them, we don't get a great deal of success in them [families who have DNA'd] coming in. But when, say, a nurse or when I phoned them and said, 'Why haven't you come in for your appointment? You're due it, come in.' they tend to turn up. I mean, I'm not particularly, like, fluffy about it...I'm like, 'It's Dr *****; why have you not turned up? You've missed an appointment, come. When's good for you? Right, done. If you don't come, I'm going to phone you up again.' Because I think when it's non-clinical [employee], it just doesn't take; it's just dismissed." [GP 1]*

This could be related to a clinician's perceived respect, authority or trust over a non-clinician. Communication with a clinician known to the family may make parents feel more compelled, especially if the request is not delivered in a *"fluffy"* manner [GP 1]. The efficacy of this approach is discussed further in Theme 4. Clinicians will have more knowledge of the vaccines and an increased awareness of the importance of vaccination than non-clinicians.

"A nurse can educate a mother much more than a receptionist asking why their child DNA'd." [Practice Manager 2]

A commissioner detailed an initiative to equip administrative staff with more vaccination-specific knowledge, which may be needed when contacting parents to arrange vaccination appointments.

“Sometimes it's not clinicians that are having these and conversations, very much you'll find that it's your receptionist who's calling your patient, and so they need to be able to have a level of confidence to have discussions” [Commissioner 1]

Thus far, Theme 3 has discussed the importance of effective call and recall procedures, including the occasional need for repeated follow-ups. However, in contradiction, all participants reported that repeated reminders, either in digital or physical form, do not work to encourage vaccination uptake or appointment attendance. One reason for this was that lower levels of literacy were reported as a more significant issue in Deep End GP practices, which GP 4 reported was *“something which I think we [Deep End GP practices] underrepresent”*.

“You can produce endless leaflets all you want, they're not go anywhere except the bin, digital or physical, but they go nowhere, they're completely and utterly pointless. We always get given them for various things, for everything it's, 'give a leaflet, that'll help'. Again, coming back to our literacy, it doesn't, and no one cares...completely a waste of time. All these national campaigns and all that, waste of time” [GP 1]

Another participant argued that

“...it [vaccination information leaflets] only works if there's a follow-up, so if you say 'I'm going to give you this, come back and talk to me about it [vaccination]'...there's some patients I know will go on NHS England, and they'll Google what they've got wrong with them. Even though they might be chaotic, I know they'll be on NHS.UK...” [GP 2]

Another challenge to effective communication is language barriers. When vaccination providers cannot communicate effectively with parents, arranging appointments and addressing potential concerns is more difficult. If English is not a family's first language, it may signal they migrated from another country. As well as having difficulties communicating with parents for whom English is not their first language, there is the consideration of differing vaccination schedules. Children must be vaccinated according to the UK schedule, which could mean re-vaccinating against the same antigens if administered at different ages. If language barriers are present, it is more difficult to ascertain which vaccines a child has received and, subsequently, which ones they need to catch up on.

“...children from other countries, of which there's quite a lot of in Middlesbrough, and asylum seekers, there's language barriers but also the people arriving, they may have started their children's vaccinations in their own country, and they've

come with bits of paper in different languages that says what they've had and what they haven't had, and if it doesn't really match up exactly with what our vaccines are." [Public Health Employee 1]

Practice Manager 2 stated, "*BAME is our biggest problem*", referring to the outdated term meaning Black and Minority Ethnic groups. The issue with broad statements such as these is that it is unclear how ethnicity is linked to low uptake. The participant then described language barriers and differing cultural perceptions of vaccination, which other participants supported.

"No matter what we do, it doesn't increase attendance because it's cultural. A lot of it's cultural...non-English speaking..." [Practice Manager 1]

This contrasts with Theme 1, where it was explained that professionals from the wider vaccination system attributed the higher uptake in the North East to a lack of ethnic diversity. Much like the term "*chaotic families*", the terminology used is important to explaining and framing the issue correctly. Being specific rather than general is beneficial to understanding the mechanisms that may cause these associations,

Two quotes summarise the essence of this theme:

"Once we've got them in and they've had their injections, it's fine. It's getting them in." [Nurse 1]

"It's the Pareto effect, isn't it? It's quite easy to get the first 80/90% just by doing the routine things, but you need to put more effort into that last or 10%." [Commissioner 3]

5.3.6. Theme 4 – Information acquisition, knowledge processes, and balancing informed choice against public health benefits

Theme 4 describes the importance of parental education and health literacy, including vaccine and vaccination-specific knowledge, and some social issues that have affected the perception of vaccines and vaccination. It discusses balancing individual and public health benefits in a society that supports informed vaccination personal decision-making.

Interviewees reported lower uptake of the pre-school booster (Diphtheria, Tetanus, Pertussis, and Polio – DTaP/IPV) and the two MMR doses, especially the second (MMR2). The first MMR vaccine (MMR1) is administered at one year of age, whereas the pre-school

booster and MMR2 are administered at three years and four months. Low uptake for the pre-school booster and MMR2 was linked to difficulty scheduling appointments. Unlike the first set of vaccines administered at 8, 12 and 16 weeks (for more information, refer to Section 3.2.2, *The English childhood vaccination schedule*), mothers are often on maternity leave and have more frequent contact with their healthcare providers during this period.

“...when I have spoken to families, I think they just forget about it, and it's not really on the top of their list of priorities. When they're newborn, you have your GP check, and then you go straight in with the nurse, and then I tend to put them in four weeks after, and then four weeks after, and then it's still fresh in their minds. By the time they're one year old, it's a couple of years later, they're busy. They're probably back at work, or if they're not at work, they're busy doing things, or their child's at nursery a lot of the time, and it's difficult to try and get them booked in.” [Nurse 2]

However, for the MMR vaccines in general, there are still some persisting issues with vaccine hesitancy and the link to autism (see Sections 1.3.3, *Vaccine hesitancy*, and 1.3.4, *The MMR crisis 1998*). Vaccine hesitancy refers to delaying or declining vaccination, often linked to concerns or fear.

“[Discussing recent events that impacted the perception of vaccines and vaccination]...the first was the MMR scandal and the discredited...Andrew Wakefield did more damage for the health and well-being of both children and the wider community than any other doctor other than Harold Shipman. Although probably equally as damaging in terms of the number of people that would have been harmed by his now rightly discredited paper. The second was COVID, and the massive amount of...it ranged from conspiracists through to understandable hesitancy. I don't want to discredit people who don't have vaccines as conspiracists because they're not. We have an awful lot of worried-well and concerned Mam's and Dad's, and that's completely and utterly understandable. But, we were fighting against the conspiracy movement because it was tied up with significant restrictions placed on our liberties, and people associated one with the other.” [Healthcare Delivery Partner 1]

The above quote references several important features related to information acquisition and knowledge processes – the 1998 MMR crisis, COVID-19, vaccine hesitancy, anti-vaxxers, and the intertwinement of health, politics, and liberty – which are central to this theme.

Deep End NENC GP practice employees reported some “anti-vax” parents, but they were primarily not the reason for low uptake. GP 1 reported an estimated five anti-vaxxers in each cohort, a small number considering their patient population. However, many

participants suggested vaccine hesitancy was an issue associated with the persisting effects of the 1998 MMR crisis.

“...we just scrape in with the childhood 0-5, but not the MMR, and that's because of all of this bad, fake news that it caused autism, and all the rest of it, and we've never recovered from that...” [Practice Manager 1]

Vaccine hesitancy related to the 1998 MMR crisis was reportedly more common in multi-child families. This was associated with an older sibling reportedly having an alleged reaction to the MMR vaccine or having neurodevelopmental difficulties, such as autism spectrum disorder or attention deficit hyperactivity disorder (ADHD), that parents feared were linked to the vaccine. Consequently, the younger children were not vaccinated for fear they would have a similar outcome.

“I can think of particular cases where mums got a child who's got autism or learning difficulties, totally unrelated to vaccines and things, but may then think ‘Well, actually, I don't want to have my younger children vaccinated.’” [GP 2]

Other interviewees supported the claim that the 1998 MMR Crisis and COVID-19 are important events affecting the perception of vaccines and vaccination. As reported by Public Health Employees, the COVID-19 pandemic reportedly contributed to an increase in vaccine hesitancy at the local population level.

“[Discussing the reasons for low MMR vaccination uptake]...the MMR from the 1990s, the anti-vax movement and conspiracy claims, probably on the back of COVID...” [Public Health Employee 1]

“...I've probably seen a little bit of an increase in that over COVID – of worry of vaccines – and there's a lot of myth-busting as well...” [Public Health Employee 2]

One participant hypothesised why concerns relating the MMR vaccine to autism spectrum disorders persist 25 years later: a lack of re-education campaigns to change the narrative. The importance of accurate vaccination knowledge is discussed later in this theme.

“[During] COVID, we were told every day on the news, and in advertising campaigns, it was going to kill us, so everybody wanted to be vaccinated. Even those that didn't need vaccinating at the time, they wanted it before their group hit because of the constant information filtering through. That isn't there with childhood immunisations...” [Practice Manager 1]

Unrelated to hesitancy concerns, it was suggested the public may be “vaccined-out” [Nurse 2] after COVID-19, which could be associated with the recent absolute decline in all childhood vaccinations. On the one hand, participants suggested that more vaccine

promotion is required; on the other, too much information can create resistance. The frequency of vaccination information and communication must be carefully considered because

“...there's a fine line between nudging and making people feel resistant to the message.” [Public Health Employee 2]

One aspect that encourages uptake amongst vaccine-hesitant parents is strong, trusting relationships between themselves and their child's vaccination provider. However, as discussed in Theme 1, there has been a decline in these relationships in the current climate of the NHS.

“What we know through research, and so on, is the power of the trusted voice.” [Commissioner C]

A mutual level of trust between parents and providers allows for a more open dialogue about vaccination to discuss hesitancy and the benefits of vaccination. One participant mentioned they used to attend the homes of unvaccinated children unannounced because there used to be a greater level of familiarity between themselves and their registered families.

“I've been a doctor in a Deep End practice for maybe 30 years and, before I merged, I was in a smaller practice. In the smaller practice it was easier to do because I knew the patients more. There was times I will go out to the house and just knock on the door when they weren't expecting me and immunise the kids there in the room because I couldn't get them down.” [GP 3]

This is only possible with strong patient-provider relationships and adequate capacity on behalf of the vaccinator. These trusting relationships are reportedly vital for the “*chaotic families*” mentioned in Theme 3 to support vaccination uptake.

“[Discussing chaotic families]...they need the more personal touch, and not just personal, but continuity.” [GP 2]

If a trusted source does not adequately address concerns, individuals are more susceptible to other less-accurate information and sources, such as family members.

“When you talk to people they're just like, ‘my mam and dad said this’, or, ‘my family member said that’, or, ‘my sister didn't get their children vaccinated’” [Nurse 2]

To support those experiencing vaccine hesitancy, a non-pressuring, personalised approach is required. Participants were keen to express that using force does not encourage uptake. However, in Theme 3, GP 4 suggested they were not “*woolly*” when

following up on DNAs, which was allegedly successful in encouraging appointment attendance.

"It's much more about understanding. In some ways, what you shouldn't do is easier [leaflet and repeated reminders], what you should do could be harder, like opportunistic [vaccination], understanding what the barriers are, talking to the populations, they are the crucial things. The big no no is telling people what to do."
[GP 3]

"Browbeating and bashing and threats don't work; it's support, identifying need, and answering questions." [GP 4]

Another facet of informed-decision making is the importance of parental knowledge of vaccines and vaccination. Lack of disease awareness is reportedly an increasing issue. A significant proportion of the UK population has not witnessed the potential impacts and long-term implications of contracting vaccine-preventable diseases because prevalence has been significantly reduced due to the success of the vaccination programme.

"...in my lifetime, I've seen children going blind, I've seen children being disabled from vaccine preventable diseases, very few parents have. And sometimes I would say that, 'I know this is really, really difficult, but this is what these diseases can do', [mimicking parent] 'Oh God, I forgot about that!', because you don't see it..."
[Public Health Employee 2]

"...I think a little bit of complacency has probably snuck in at the fact that they don't see these diseases anymore..." [Public Health Employee 1]

Two participants referred to this as the childhood programme being a "victim" [Public Health Employee 2 and Commissioner 2] of its success. Similarly, it was believed that some parents are unaware of why multiple doses of the same antigen are required and subsequently view the schedule as a "pick 'n' mix" [Public Health Employee 1]. However, as this theme suggests, information regarding the impact of vaccine-preventable diseases is best provided by a trusted healthcare professional rather than vaccination promotion campaigns. Awareness of vaccine-preventable diseases and the need for multiple doses are important to encourage parents to complete their child's schedule for maximum protection.

However, when parents decide not to vaccinate, it is important to ensure their decisions are informed, meaning they understand the risks of not doing so.

"...I want us to have conversations with people that enable them to have an informed choice, even if I consider that choice to be unwise. What I don't want

people to have an ill-informed, or not informed, decision not to allow their child to be vaccinated..." [Healthcare Delivery Partner 1]

Childhood vaccination is unique compared to other vaccines administered throughout the life course because they cannot self-consent. The decision is being made on behalf of another individual, and therefore, the implications reach beyond the decision-maker to the child and the wider population through herd immunity.

"...people should be able to have a choice, but the other part of me thinks: the child doesn't have a choice; it's somebody else making that choice for them. I mean, if you went blind because your mum didn't get your measles..." [Practice Manager 1]

"...I wonder if they'll ever be a kid who sues their parents if they get a horrible measles complication later in life for not getting them vaccinated..." [GP 3]

Despite this, there is no official consent procedure; attendance at the vaccination appointment is taken as consent.

"The parent needs to consent, but actually, there isn't a consent process; you just literally turn up for your appointment." [Public Health Employee 1]

Childhood vaccinations are not mandatory in the UK, but parents must attend their registered GP practice to sign a form indicating if they do not wish their child to be vaccinated. Thus, the schedule is treated as an opt-out process. Parents will continue to receive communication from their GP practice about their child's vaccination appointments until they formally opt out.

Interviewees from the wider vaccination system reported a unique tension between parents who decide not to vaccinate their children and the population's health, sparking debates about individual liberty in a UK context.

"Do we say, 'Well, the most important thing is people get to make a choice!'; or do we say, 'Well, actually, all these people making a choice have now put all these people at risk, because we don't have herd immunity anymore because they didn't feel it was right for their child.' It's looking at how you manage that because, ethically, you don't want to take people's choice away, but on the other hand, I'm not into mandatory vaccination or anything – I think that's absolute nonsense – it doesn't do anything except annoy people, but I do think that there is a really big conversation." [Commissioner 1]

As with any pharmacological intervention, there is always the risk of adverse effects and negative reactions. Thus, in pursuit of full coverage, some children will experience these. This could be difficult for parents to reconcile because their child may be harmed, but on a population level, a calculated risk has been made to benefit the majority.

“Within that desire to have 100% coverage comes the knowledge that there will be harm to individual children. As a society we have decided that the benefit outweighs the harm.” [Delivery Partner A]

However, it was suggested that parents view vaccines differently from other pharmacological interventions because they are (primarily) administered through injection. One participant believed this was because immunisation via injection was perceived as more “*potent*” and “*irrevocable*” [Public Health Employee 2] than, for instance, the childhood flu vaccine administered via nasal spray.

“Some parents don't have the confidence to deal with their child receiving an injection; that's very difficult. Whereas the nasal drop doesn't seem as bad. That they're [injections] hurting them, that it may do something, the links with Autism, and that we're damaging this perfect baby that they've given birth to.” [Public Health Employee 2]

Overall, Theme 4 demonstrates that the concepts of vaccination, informed decision-making, and public health are individually complex and made additionally so when combined.

5.3.7. Theme 5 – What actually works? addressing the challenges of delivering, commissioning, monitoring, and supporting the childhood vaccination programme

Theme 5 analyses some initiatives and interventions aimed at improving or supporting the childhood vaccination programme, including a pilot organised by the Deep End Network NENC. This theme captures the conflicting perspectives on the best means of increasing uptake and suggests that already established mechanisms, such as Health Visitor service, may be most effective.

The interviews provided a conflicting account of what works to encourage appointment attendance and improve childhood vaccination uptake – a fact mentioned several times throughout this analysis. One participant stated that, ultimately, it is a parent's responsibility to ensure their children are vaccinated. Providers reported feeling restricted in their ability to proactively address the challenges and barriers faced within the childhood vaccination programme. Subsequently, addressing the social determinants of health was reportedly the responsibility of the wider vaccination system.

"...at the end of the day, it's the parent's responsibility to be proactive and vaccinate their children. I feel like we can only do so much..." [Nurse 2]

Commissioners and Public Health Professionals claimed their teams recently engaged in behavioural insights work. Interviews and focus groups were performed with parents, families, providers and other relevant stakeholders to understand the lived experience of the childhood programme – another example of communication between providers and the wider vaccination system, as discussed in Theme 1. In their interview, Public Health Employee 1 provided a detailed overview of their findings.

"A lot of the local authorities, ourselves, have done a lot of behavioural insights work around how best to target certain [areas/groups at-risk of low vaccination uptake]." [Commissioner 4]

Despite being involved in behavioural insights work themselves, Commissioner 1 felt that it was over-saturated, and the findings often related to nudge theory and appropriate communication. Nudge theory involves gently steering audiences to act in a certain way (such as vaccinating their children) whilst ensuring decisions are made of their volition (Thaler, 2009).

"There comes a point, doesn't there, where you think do we need to know much more now? I think at the end of the day, behavioural insights is still just really around nudge theory, and it's about the communications. I haven't seen enough evaluation yet. I query whether we're getting to saturation point with it really." [Commissioner 1]

However, this could be considered saturation or confirmation that these barriers still exist. Both are useful outcomes. On the other hand, the resources used for the behaviour insights work could be utilised elsewhere for more practical interventions.

Theme 4 discussed issues of vaccine and vaccination awareness and knowledge. One solution to these issues was education campaigns using letters, leaflets, and posters. The *"framing"* [Public Health Employee 2] was carefully curated in these campaigns using various psychological tools to portray vaccines and vaccination as the safest, correct, and most common method of protecting children from disease. For instance, one of these tools was framing the vaccination schedule as a set rather than individual vaccines using the phrase *"five steps to protection"* [Public Health Employee 2]. This could help address the low uptake for MMR2 and the pre-school booster, which may be

affected by a lack of awareness of the importance of multiple doses (as explored in Theme 4).

These education campaigns would visually reflect the target low-uptake population by utilising various languages and tailoring the message to address their specific concerns. One participant mentioned that information campaigns in different languages are needed to equip parents with important vaccination information for whom English is not their first language.

"[Discussing what may work to improve vaccination uptake] Promotion, and education, and education in their language." [Nurse 2]

This would help address the language barrier issues explored in Theme 3. However, it was also suggested in Theme 3 that education campaigns such as this are a "waste of time" [GP 1] because leaflets are "not going anywhere except the bin" [GP 1]. One participant felt that producing education campaigns in different languages was insufficient.

"..they [any organisation/team attempting to address barriers to vaccination uptake] think that providing patient information leaflets in various different languages ticks the box, and therefore, we have accommodated people's different requirements, and it is so much more than that." [Healthcare Delivery Partner 1]

It could be argued that while these education campaigns may not be wholly successful, they are attempting to address the issue. It has been suggested that more education and knowledge are required whilst simultaneously claiming education campaigns do not work to improve uptake (as discussed in Theme 4).

One of the most significant challenges in delivering the childhood programme for providers is "getting them [parents and children] in" [Nurse 1], mentioned in Theme 3. One intervention aimed at minimising this was pop-up vaccination clinics in nurseries in socioeconomically deprived areas of South Tyneside and County Durham. Parents who participated reported these a success because it was more convenient than attending their GP practice, but this was not necessarily the purpose of the intervention.

"...basically, they would have, likely, persevered and got their child vaccinated at their GP surgeries anyways, and it just made it a lot more convenient, which is great, but, actually, that wasn't the point of it. The point of it was disadvantaged people who wouldn't normally access it." [Commissioner 2]

This demonstrates the differing metrics of success of an intervention. Commissioners view this from a perspective of "opportunity cost" [Commissioner 3], meaning the

funding used for this intervention could be employed elsewhere where it could better target *“disadvantaged people who wouldn't normally access it”* [Commissioner 2]. Reportedly, pop-up clinics can be more costly than beneficial but have been utilised more since their effectiveness during the pandemic for the COVID-19 vaccine.

“...everybody's very keen to do pop-up clinics because it worked well for COVID, and that seems to be a big thing...That's the first thing I think doesn't work. There's so many initiatives at the moment to improve vaccination, and generally, the evaluation on them is very poor. I find that a lot of evaluations, the evaluation metrics, are not particularly well thought-out at the beginning of the project, it tends to just be numbers, but the numbers don't mean a lot...” [Commissioner 2]

As the above quote suggests, evaluations solely based on the number of children vaccinated do not offer the whole perspective – a fact discussed in Theme 1. Conducting thorough evaluations is crucial to ensuring interventions are useful and cost-effective.

Reducing the burden of programme delivery was one aim of the Deep End Network NENC childhood immunisation intervention (refer to Section 5.2.3, *The Deep End Network North East and North Cumbria*, for more information). The Network proposed a multi-disciplinary team comprised of administrators and vaccination-trained nurses who would undertake a two-week rotation in each interested practice. It was suggested the vaccination-trained nurses could offer extra childhood vaccination clinics and/or a roving service to vaccinate children in their homes.

“[Discussing the Deep End NENC intervention]...a childhood immunisation catch-up team that will work with practices to identify children who are unvaccinated through ordinary engagement routes, and provide additional resource, and go and work with those children and those families in an enhanced way...” [Healthcare Delivery Partner 1]

The intervention was the product of behavioural insights work performed by commissioners with members of the Deep End NENC Network. The insights work identified how these practices struggle with meeting their QOF targets, meaning vaccinations were not being administered in the appropriate timeframe. Thus, the aim of the intervention was three-fold.

“...we expect an increase in uptake, and therefore, that has a public health benefit to the whole of the population, not just the individual child, in terms of trying to reach herd immunity within a population. So, there is a population benefit, there's an individual child benefit, but then there is a system benefit that will enable those practices to reach their QOF targets and therefore release the income that is associated with that attainment...” [Healthcare Delivery Partner 1]

Overall, providers viewed the intervention positively, albeit with some foreseeable issues with implementation and measured scepticism. The nurses interviewed were the most enthusiastic about the intervention, reporting that it would benefit their practices, but in different forms. One nurse felt that additional staffing capacity to offer more vaccination appointments would be helpful.

"I think we probably would benefit...because I'm the only practice nurse, and my clinics are full all of the time for all appointments until they put extra appointments on in a month's time..." [Nurse 2]

Although, the roving team aspect was received most favourably. This would remove many barriers for families that find it difficult to attend the practice for vaccination appointments, which was reported in Theme 3 as one of the most significant challenges of delivering the childhood vaccination programme.

"...definitely trying to access people's homes would help, because sometimes they're just really busy, and they've got different issues in their life that, for them, are more important than vaccinating their children. I think if somebody came to them and they didn't have to try and organise things and get them there. A lot of our families have multiple children, and it's just difficult to try and organise, especially if they're young, or if they're in school..." [Nurse 2]

The core principles of the Deep End NENC intervention address many of the challenges discussed. However, there was some apprehension about its potential impact.

"[Discussing the Deep End NENC intervention and the behavioural insights work conducted by local authorities]...I kind of get the feeling that the practices are a little bit, 'What are they going to come in and do that we haven't already tried?' And I think the difference is that the work that we're doing has got the behavioural science behind it..." [Public Health Employee 2]

This was supported by GP 3, who suggested that practices may feel disheartened if offered the intervention and would view it as *"failing"* [GP 3]. Another participant felt that a roving team would not benefit families with *"chaotic"* personal lives, as discussed in Theme 3.

"...if I had a population that were particularly resistant, then then a roving team, for example, would be really helpful. But my population isn't massively resistant, it's they're chaotic. The roving team isn't necessarily going to solve that..." [GP 1]

In the quote above, GP 1 suggested that the roving team element will not *"solve"* the issue of families with *"chaotic"* personal lives being at risk for low vaccination uptake. It was discussed in Theme 3 that *"there's something about planned care that some of our patients just cannot manage"* [GP 2]. A roving team would still require planning, as the

team would need to ensure the children and parents are in the home. Similarly, if barriers to uptake were based on cultural reasons or language issues, these challenges would exist for the intervention team.

“...if it's cultural, the fact that they're at home makes no difference. I think for a lot it will make a difference, and it'd be really interesting to see, and I'd be more than excited to try it to see. And then maybe, as long as there's a feedback element as to what the barriers are for them, because if the barriers are the same for them as us, it's a bit of a pointless exercise, isn't it?” [Practice Manager 1]

“...the biggest thing for us would be to ring the patients to come in [who have DNA'd], and that could be done remotely, that doesn't need to be in practice. I mean, obviously again, admin, to having it great, it frees up my admin, but that's probably more of staffing issue rather than a vaccination issue. For us, roving clinics aren't a massive issue...I don't think we need anything like for roving team for the kids and stuff because they can come in, it's just whether they choose to or not is another question...” [GP 1]

However, in Healthcare Delivery Partner 1's description of the Deep End NENC intervention (presented earlier in Theme 5), the main aim was to support timely vaccination by providing additional staff, not to “solve” all barriers to uptake. Also, it would temporarily alleviate transport and childcare concerns for families, which were discussed in Theme 3 as barriers for some families.

Some foreseeable issues of implementation were reported. Some were practical issues, such as (clinical and non-clinical) physical space for the intervention team to work and access to IT systems; others were more emotional concerns. As discussed in Theme 3, “chaotic” families were often those involved with safeguarding. These families are often at risk of low vaccination uptake. The Deep End NENC intervention was targeted at these families.

“...they're the families that we're mainly concerned about, the ones who are on our list that we discuss at safeguarding meetings...” [GP 2]

Subsequently, there was a concern that the roving team could be entering potentially unsafe environments. This is a difficult concern to navigate. Children in these situations would benefit the most from a roving service, but staff safety is equally important.

“...the other thing, if I was you and I was setting up such a service, for me it would be making sure that there's somewhere on the form that the practice submits to say, 'Don't go to these people', for any violence or anything, because you need to exclude them. You don't want nurses walking into a house where patients could be potentially violent...” [Practice Manager 1]

Excluding these children from the intervention would be a significant oversight. More investigation into this would be needed to ensure the safety of all parties.

Participants discussed the long-term impact of the intervention. The intervention was reactive in nature; the two-week period in each practice would address a financial issue and ensure that children in the cohort were vaccinated. As discussed earlier in Theme 5, the intervention will not “solve” barriers to access and challenges to delivery. One participant reported that they would welcome the intervention if the team were knowledgeable about improving vaccination uptake in underserved communities. Learning new approaches to delivery and being supported by the Deep End NENC Network was equally important as a more practical means of support.

“...it might be worth, if we could have a meeting beforehand with the team, a couple of weeks, or a few weeks before they come, so we understand what's worked elsewhere, particularly with communities I'm not familiar with...” [GP 3]

“...it's not even so much funding, help and support is enough...” [Practice Manager 2]

This knowledge would remain with the practice beyond the two-week intervention period. The legacy of intervention was discussed from a commissioning perspective. It is reportedly difficult for those making high-level financial allocation decisions when several low-level initiatives are skewing the perspective of the true amount of resources required to deliver the current outcome.

“...the cost model is really what's paid from the GP contract, and all this other activity that we're doing around the outside of it, is anybody doing the sums to put in that other activity, to get a clear view of really what is the financial cost of having these programmes?” [Commissioner 3]

Thus, investigations into the health/economic cost would be required if the intervention were to continue.

Whilst the Deep End NENC childhood immunisation intervention is a new creation, vaccinating children in the home is not. Health visitors used to offer this service. Local authorities commission health visitors as part of the 0-19 Healthy Child Programme, which participants felt does not currently function properly.

“Our health visitor services is...the word ‘disarray’ may do it a disservice, but I think it's similar in a lot of areas.” [GP 4]

One Public Health Employee reported having previously worked as a health visitor during the time they used to vaccinate. They recalled the importance of the health visitor, not only for vaccinating but for addressing vaccine hesitancy. This links to Theme 4 and the importance of strong, trusting parent-provider relationships.

“...we [health visitors] would give them their first immunisations and follow the schedule through. The benefits of that approach is that you really had a really good rapport with parents, carers and children. And also, we would do opportunistic catch-ups, so we would do them in the home.” [Public Health Employee 2]

In their behavioural insights work, one commissioner reported that participants in their focus groups also recalled the usefulness of the health visitor service.

“[imitating focus group participant] ‘it’s all very well having all these leaflets and going on the internet and everything but when I had kids’ – lots of these were grandparents – ‘your health visitor came, and they really talked to you about the vaccines’” [Commissioner 2]

Thus, there are already mechanisms to deliver this as a consistent service, but it would require allocated funding and expanding the health visitor service.

“I think that as a system, as a whole, we may be not using that part of the influence, particularly of that last 10-15% of parents who aren’t bringing their children along. And so, we could be making more use of the health visitors, but a part of that is making sure that that service is well specified and obviously funded to do that work. It takes time.” [Commissioner 3]

Theme 5 was aptly titled “What actually works?” emphasising the question mark. While unpacking the interventions currently underway, it is clear that a “one-size-fits-all” approach is neither beneficial nor possible.

5.4. Discussion

5.4.1. Addressing the research questions

The interviews sought to explore the following three research questions:

Research Question 1: What insight do professionals involved in commissioning and monitoring the childhood immunisation programme in the North East of England have into potential reasons for the comparatively higher levels of childhood vaccination uptake?

Research Question 2: What are the realities experienced by professionals in delivering the childhood vaccination programme in areas of high socioeconomic deprivation in the North East of England?

Research Question 3: What are the opinions of professionals involved in delivering, commissioning, supporting, and monitoring the childhood vaccination programme on current initiatives and interventions to improve provision in the North East of England, with a focus on areas of high socioeconomic deprivation?

Theme 1 (The North East paradox: exploring the childhood vaccination uptake in the North East of England) addresses Research Question 1 by identifying two main reasons for higher uptake in the North East: the greater prevalence of stability and the lack of groups who may face more barriers to uptake. The greater prevalence of stability allegedly impacts three factors related to childhood vaccination uptake: the ability to foster a greater sense of community, more consistent local healthcare services, and easier uptake monitoring. Moreover, the North East is one of the most monocultural regions in England (see Section 5.1.2, *The North East of England: a brief history*, for more information). Healthcare and the childhood vaccination programme have, historically, not had to address language barriers and cultural perceptions on the same scale as other regions. The North East also reported higher uptake in local authorities with high levels of socioeconomic deprivation than other regions. Thus, the high levels of vaccination uptake may not be related to above-average provision but social processes that interact differently with the childhood vaccination programme.

Moreover, Themes 2 (From policy to practice: the childhood vaccination programme as a system and data flows), 3 (Vaccinating the minority: the challenges of delivering the childhood vaccination programme to families from underserved communities), and 4 (Information acquisition, knowledge processes, and balancing the informed choice against public health benefits) describe the realities of delivering the childhood vaccination programme in the North East of England in areas of high socioeconomic deprivation, thus addressing Research Question 2. Despite overall high levels of uptake in the region, the reality of delivering the programme was not as easy as it may appear.

There were reported financial concerns related to the Carr-Hill formula used to calculate practice income and difficulty with achieving the levels of uptake required for QOF. Providers in Deep End GP practices believed there was a greater prevalence of “*chaotic*” families, children with uncertain vaccination statuses, and those who may face greater barriers to uptake. Although non-specific to Deep End practices, there was allegedly a lack of parental vaccine-preventable disease awareness, partially due to the success of the childhood vaccination programme and subsequent lack of exposure to potential complications. Health promotion campaigns were suggested to be ineffective, especially in low literacy settings, such as Deep End practices.

Theme 5 (What actually works? Addressing the challenges of delivering, commissioning, monitoring, and supporting the childhood vaccination programme) explores some of the potential solutions to the challenges identified in Themes 2, 3, and 4, and thus addresses Research Question 3. However, there was no consistent evidence of what works to improve uptake or reduce the burden of delivering the childhood programme. There were multiple conflicting suggestions from a variety of participants. Interviewees were sceptical of most interventions discussed. However, a common thread throughout this thesis is the national and global decline of childhood vaccination uptake. Efforts are required to prevent further decline and protect children against morbidity and mortality associated with vaccine-preventable diseases.

The difficulty is that each GP practice and patient population are different; what applies to one practice/family may not be helpful to another. It is a fair assessment to suggest that these are categorical of English healthcare and not just relevant to the childhood programme. Still, they are unique because the effects begin at two months old and can have lifetime implications. The following quote summaries the sometimes-overwhelming task:

“...the thing about vaccination and immunisation, it is something that you have to attain and achieve constantly. There is never an end point and never an end goal...”

[Healthcare Delivery Partner 1]

This discussion was intentionally brief, as the qualitative findings are integrated with the quantitative in Chapter 6, where they are contextualised by the wider literature. Subsequently, the following section explores only the limitations of this qualitative

component; the strengths are presented in Chapter 6, where they can be adequately demonstrated as a mixed methods project.

5.4.2. Limitations

There are three main limitations of this work. Firstly, participants representing the vaccination service providers were only recruited from Deep End NENC GP practices. Whilst this accounts for the socioeconomic deprivation element of the research questions, it does not account for the fact that a GP practice could be experiencing the same issues but not be classified as a Deep End practice according to the criteria. This could potentially create sample homogeneity. Similarly, snowball sampling can increase the risk of heterogeneity because participants are utilising their connections and may not recommend someone with opinions they do not agree with.

Secondly, this study did not utilise an extensive double-coding process. An external researcher (TP) independently coded one anonymised transcript, and then we compared and contrasted our respective findings. Although there was a high degree of inter-rater consistency, with both TP and I identifying similar codes and agreeing on the development of the themes, it could be argued that double-coding a singular transcript does not provide enough rigour. However, a framework approach provides a transparent, comprehensive overview of the analysis process, including the relevant codes and summarises the theme according to each participant.

Thirdly, as my knowledge of the subject grew through conducting and analysing the interviews, some occasions were identified where more probing would have proved useful. Retrospectively, I could easily recognise deviant accounts because I was more aware of what was considered the norm. This is especially true from a vaccination service delivery perspective. For instance, one participant mentioned that their local authority provides the practice with a list of unvaccinated children each week. At the time of this interview, I was unaware that local authorities do not have real-time access to CHIS data systems. Further probing into this would have been useful.

5.4.3. Conclusion

Chapter 5 concludes the empirical elements of this thesis and presents the qualitative component of the mixed methods study. Chapter 6 aims to collate the findings of the umbrella review and the mixed methods study, contextualise them in the wider literature, and discuss their implications.

Chapter 6. Discussion and Concluding Thoughts

6.1. Introduction

6.1.1. Chapter overview

This chapter will focus on bringing together the findings of the umbrella review, the quantitative analysis, and the qualitative interviews, and contextualise them using the wider literature. Subsequently, Chapter 6 addresses thesis Objective 4:

Objective 4 – Connect the findings from the umbrella review, quantitative analysis, and qualitative study to provide a comprehensive overview of socioeconomic inequalities in vaccination uptake on a global, national, and regional level.

Firstly, this chapter provides a succinct overview of the main findings from each empirical element. Afterwards, the findings of the umbrella review and quantitative and qualitative studies are integrated and contextualised using the wider literature. The final version of the patient-centred access to vaccination framework is presented, now grounded in the primary data. Following this, the overall message of the thesis is discussed, including the implications of the integrated findings. To conclude, recommendations are made, and methodological strengths and limitations outlined, before suggestions for future research and concluding remarks are provided.

6.2. Synopsis of Key Findings

6.2.1. Umbrella review

The first empirical component was an umbrella review exploring global socioeconomic inequalities in routine vaccination uptake. In addition to ascertaining whether these inequalities exist, the mechanisms contributing to this association were also investigated. The main findings were narratively synthesised according to the economic status of the country setting, and the mechanisms were mapped to a patient-centred access to vaccination framework informed by Levesque *et al.*'s (2013) work.

Twenty-six systematic reviews were analysed, equating to 595 unique primary studies. There were several key findings: Firstly, in LMIC, there appears to be consistent evidence for inequalities, such as lower vaccine uptake amongst disadvantaged socioeconomic groups or higher vaccine uptake amongst advantaged socioeconomic groups. Secondly, the picture was more variable for reviews analysing HIC with evidence for inequalities and inverse associations (either low uptake for advantaged or high uptake for disadvantaged socioeconomic groups). Thirdly, most reviews provided mechanisms that may explain the association between socioeconomic position and vaccination uptake. The two most frequently cited mechanisms were reduced vaccination knowledge (access to relevant information and/or ability to understand this information) and a lack of confidence (in vaccination in general or in oneself to make decisions about uptake). Finally, reviews that narratively synthesised their findings included a broader range of outcomes than those that conducted a meta-analysis, identifying more evidence of inequalities.

6.2.2. *Mixed methods methodology*

The findings of the umbrella review were utilised to refine the scope of the thesis on childhood vaccination in pursuit of an investigation into instances of low uptake for advantaged socioeconomic groups. The literature review of Chapter 3 suggested a mixed methods study would be a beneficial contribution to the discourse. The quantitative element could analyse the impact of specific COVID-19 events on childhood vaccine uptake using methods that would allow the cumulative effect to be ascertained. These findings could be used to identify a regional focus, alternative to London, for the qualitative component. The experience of vaccination service providers was lacking, as many of the qualitative studies identified explored parental attitudes. Thus, a qualitative inquiry could be undertaken with service providers to explore their experience of COVID-19 on the childhood vaccination programme. To assess the impact of socioeconomic inequalities, these providers could be sought from GP practices in socioeconomically deprived areas to maintain this lens of inequality. Thus, this approach was taken. The mixed methods study used an exploratory sequential design to integrate the quantitative and qualitative components. The patient-centred access to vaccination framework was also adapted in Chapter 3, informed by the umbrella review findings and incorporated

with the Socioecological Model of Health, which was utilised for the mixed methods study.

6.2.3. Quantitative component

The quantitative element analysed Cover of Vaccinations Evaluated Rapidly (COVER) childhood vaccination uptake data, specifically, the MMR vaccine and the pre-school booster. Using piecewise regressions, it explored the interaction effects of local authority deprivation level and three COVID-19 events – the first lockdown and Phase 1 and Phase 2 vaccination rollout on uptake. Further analysis investigated the additional effects of region.

The exploratory analysis suggested that the uptake of pre-school boosters and MMR vaccinations in England had declined before COVID-19. Still, the rate of this decline appeared to increase around this event. It also suggested that different socioeconomic groups and regions may differ in their experience of childhood vaccination uptake. The piecewise regressions identified an overall lockdown-associated decline in vaccination uptake. This was not found for Phase 1 or Phase 2 COVID-19 vaccination rollout.

The deprivation level of a local authority appeared to affect the change in uptake during COVID-19. The results suggested more evidence of lockdown-associated socioeconomic inequalities in vaccination uptake for both the pre-school booster and the MMR vaccine. However, these effects were more prominent in the context of the MMR vaccine – greater uptake for the least deprived and lower uptake for the most deprived local authorities.

Further analysis into the effect of region on the interaction between deprivation and COVID-19 identified stronger evidence of socioeconomic inequalities in vaccination – greater uptake for the least deprived local authorities and lower uptake for the most deprived – when London was excluded from the models. This suggests London could be an outlier. Evidence suggested that a clear, explicit social gradient may not exist for childhood vaccination uptake, as equally deprived areas across England experienced lockdown-associated changes in uptake differently.

The quantitative analysis identified the North East as exhibiting higher levels of uptake than other regions despite a high prevalence of socioeconomically deprived local authorities. Subsequently, this region was selected as the sampling frame for the qualitative interview study. This would allow further investigation into these higher uptake levels and offer a unique regional focus other than London.

6.2.4. Qualitative component

Qualitative interviews were conducted with professionals involved in delivering, commissioning, supporting, and monitoring the childhood vaccination programme in the North East of England with a specific focus on areas of high socioeconomic deprivation. In total, 15 interviews were performed: Deep End GP practice employees (n = 5), professionals who occupied dual roles in delivering and supporting the childhood vaccination programme (n = 3), and professionals involved in the wider childhood vaccination system (n = 7). The interviews were analysed using a framework approach, and five themes were identified:

Theme 1 – The North East paradox: exploring childhood vaccination uptake in the North East of England.

Theme 2 – From policy to practice: the childhood vaccination system and data flows.

Theme 3 – Vaccinating the minority: the challenges of delivering the childhood vaccination programme to families from underserved communities.

Theme 4 – Information acquisition, knowledge processes, and balancing informed choice against public health benefits.

Theme 5 – What actually works? Addressing the challenges of delivering, commissioning, monitoring, and supporting the childhood vaccination programme.

Two main reasons for higher uptake in the North East: the greater prevalence of stability and the lack of groups who may face more barriers to uptake. The North East also reported higher uptake in local authorities with high levels of socioeconomic deprivation than other regions. Thus, the high levels of vaccination uptake may not be related to

above-average provision but social processes that interact differently with the childhood vaccination programme.

Despite overall high levels of uptake in the region, the reality of delivering the programme was not as easy as it may appear. There were reported financial concerns related to the Carr-Hill formula used to calculate practice income and difficulty with achieving the levels of uptake required for QOF. Providers in Deep End GP practices believed there was a greater prevalence of “*chaotic*” families, children with uncertain vaccination statuses, and those who may face greater barriers to uptake. Although non-specific to Deep End practices, there was allegedly a lack of parental vaccine-preventable disease awareness, partially due to the success of the childhood vaccination programme and subsequent lack of exposure to potential complications. Health promotion campaigns were suggested to be ineffective, especially in low literacy settings, such as Deep End practices.

There was no consistent evidence of what works to improve uptake or reduce the burden of delivering the childhood programme, including multiple conflicting suggestions from various participants. Interviewees were sceptical of most interventions discussed. However, a common thread throughout this thesis is the national and global decline of childhood vaccination uptake. Efforts are required to prevent further decline and protect children against morbidity and mortality associated with vaccine-preventable diseases.

6.3. Integrating the Findings

6.3.1. Integration summary

Overall, there was a high degree of consistency across the umbrella review, quantitative, and qualitative findings. This supports the decision to perform a mixed methods inquiry, as too much heterogeneity may prevent successful integration. For example, Section 5.1.2, *Research questions*, described a qualitative interview study by Price *et al.* (2022). The study sought parents' opinions regarding the barriers and facilitators to childhood flu vaccination uptake. Authors found that parents of unvaccinated children did not necessarily hold vaccine-hesitant views, but several access barriers made the process difficult. The two most prominent barriers were limited appointment opportunities for

immunisation and vaccination not being a priority for busy parents. These were all common narratives identified in the qualitative component of the mixed methods study. This also suggests that professionals involved in delivering, commissioning, supporting, and monitoring the childhood vaccination programme in the North East of England have an accurate understanding of the parental challenges and barriers to uptake. Whilst there are many worthy points of integration, five were most notable:

- The Privilege Paradox and North-South Health Divides
- COVID-19 and the MMR vaccine
- Education and vaccination knowledge
- Is it really all about education? Practical barriers to vaccination uptake
- System of Dysfunction

6.3.2. *The privilege paradox and North-South health divides*

It has been evident in this thesis that whilst there are socioeconomic inequalities in vaccination uptake, this may not always follow a gradient, as observed with other healthcare interventions, such as cancer screening (Douglas *et al.*, 2016; Wardle *et al.*, 2016). The umbrella review identified more consistent evidence for socioeconomic inequalities in routine vaccination uptake in lower and middle-income countries, whereas higher-income countries exhibited more variable outcomes. However, it did not wholly isolate the findings related to the UK. Still, one systematic review suggested that the UK exhibited inverse associations relating to lower vaccination uptake amongst advantaged socioeconomic groups (Bocquier *et al.*, 2017). The phenomenon where areas with greater levels of socioeconomic advantage but lower rates of vaccination is known as the privilege paradox and has been discussed in the wider literature, but in an Australian context (Bryden *et al.*, 2019). Bryden *et al.* suggested that uptake was heavily influenced by geographical location and their accompanying socioeconomic demographics.

However, aside from one robustness test, the main quantitative analysis did not explicitly identify these inverse associations. Nevertheless, regional differences in uptake across deprivation quintiles were identified. The North East of England has a high prevalence of deprived local authorities (those classified as IMD “Most deprived 20%

(Quintile 1)", "Quintile 2" and "Quintile 3") and none classified as the least deprived ("Quintile 4" and "Quintile 5 (least deprived 20%)"). Despite this, main lockdown effects were identified for North East local authorities classified as "Quintile 2", experiencing an average *increase* in pre-school booster uptake of 0.316% (95% CI 0.171% to 0.461%) per quarter compared to "Quintile 3" and London. Whereas the South West experienced an average *decrease* for "Least deprived 20% (Quintile 5)" per quarter of 0.238% (95% CI -0.382% to -0.093%) with the same comparators. This demonstrates that local authorities classified as the same deprivation quintile performed differently depending on the region in which they are located and supports Bryden *et al.*'s (2019) claim that uptake is influenced by geographical area.

These findings are supported by the qualitative component. Specifically, Theme 1 – The North East paradox: exploring childhood vaccination uptake in the North East of England. Interviewees confirmed that their experience of vaccination uptake and socioeconomic position was inconsistent with a gradient. They explained how not all Deep End GP practices had low childhood vaccine uptake and, equally, some practices in more affluent areas did. Bryden *et al.* (2019) cite the increased likelihood of commitment to "natural" ways of life in more socioeconomically advantaged groups, which can lead to personal belief exemptions (PBEs). This is where individuals decline vaccinations for themselves or their children based on their views. Other studies have explored this in reference to the COVID-19 vaccine (Vlasak, Dinero and Roitman, 2023). Valsak *et al.* argue that this is a new paradigm in understanding systemic inequity because individuals from both ends of the socioeconomic spectrum are experiencing low uptake. This may be related to an increased sense of agency, whereby those with greater levels of socioeconomic resource (E.g., education and social capital) feel more confident in declining vaccinations (Swaney and Burns, 2019). A similar argument was identified in the umbrella review, which cited a greater commitment to health-seeking behaviour in advantaged socioeconomic groups.

On the other hand, the wider vaccination system professionals interviewed in the qualitative component did not suggest hesitancy-related reasons for lower uptake amongst advantaged socioeconomic groups. As providers in less disadvantaged areas were not part of the interview sample, explanations are limited. One public health

employee hypothesised several reasons for low practice uptake in these groups: such as (1) mothers who worked and did not have the flexibility to attend childhood vaccination appointments, (2) issues with substance abuse due to more financial resources to spend on addiction and (3) lack of familial support from moving for work. However, these concerns were not confined to less deprived areas. Scheduling and attending appointments were significant issues in Deep End GP practices. Thus, there are conflicting explanations for why these inverse associations exist.

Another discussion arises from this topic, namely, North-South health divides. As discussed in Section 5.1.2, *The North East of England: a brief history*, the North-South health divide is an established phenomenon where, on average, health in Southern areas is better than in Northern regions (Bambra, Barr and Milne, 2014).

“The scale of the divide is such that the life expectancy gap for women between the poorest English regions—the North East (NE) and North West (NW)—and the richest—London and the South East—was similar to the gap between the former West Germany and post-communist East Germany in the mid-1990s.” (Bambra, Barr and Milne, 2014, p. 183)

However, childhood vaccination does not appear to mimic this. Interviewees from the wider vaccination system identified two main reasons for higher uptake in the North East: the greater prevalence of stability and the lack of groups who may face more barriers to uptake, such as those who experience language barriers and differing cultural perceptions of vaccination. Greater stability impacts three factors related to childhood vaccination uptake: the ability to foster a greater sense of community, more consistent local healthcare services, and easier uptake monitoring. The North-South health divide is widely documented (Bernard, McGowan and Bambra, 2024; Hacking, Muller and Buchan, 2011; Bambra, Barr and Milne, 2014), but it is unclear why vaccination does not adhere to this. This could be linked to lower uptake for advantaged socioeconomic groups, which are less prevalent in the North than the South, or that vaccination is viewed as the “norm” in these contexts.

Nevertheless, providers in Deep End NENC practices did not have the same experience regarding the lack of groups who may face more barriers to uptake. They reported three of their biggest challenges were language barriers, differing cultural/religious perceptions of vaccination, and ascertaining a child’s vaccination status when

immunisation schedules began outside the UK. The contradiction that the North East has low cultural diversity compared to other regions, but healthcare providers in areas of high socioeconomic deprivation have a different experience speaks to wider structural issues. The clustering of ethnic minorities in deprived areas can be considered a form of structural violence (Markkanen and Harrison, 2013). The term “structural violence” was coined by Galtung and relates to

“...the type of violence where there is an actor that commits the violence as personal or direct, and to violence where there is no such actor as structural or indirect ... There may not be any person who directly harms another person in the structure. The violence is built into the structure and shows up as unequal power and consequently as unequal life chances...” (Galtung, 1969, pp. 170-171)

Thus, individuals who may experience more barriers and challenges to uptake are systematically disadvantaged because they may be clustered in areas where healthcare is already overwhelmed (Herrick and Bell, 2022).

6.3.3. COVID-19 and the MMR vaccine

The second common theme of the thesis was the MMR vaccine. It was first mentioned in the umbrella review relating to the incidence of lower childhood vaccination uptake amongst advantaged socioeconomic groups in higher-income countries. Inverse associations were also identified in high-income countries for the human papillomavirus (HPV). Indeed, in the quantitative analysis, the MMR vaccine exhibited the second lowest uptake of all childhood vaccines, with the pre-school booster experiencing the lowest uptake. However, COVID-19 lockdown-associated effects were identified more prominently for the MMR vaccine than for the pre-school booster in the piecewise regressions. The qualitative component confirmed that the MMR crisis of 1998 still affects vaccine perceptions and uptake. This was explored in Theme 4 – Information acquisition, knowledge processes, and balancing informed choice against public health benefits. However, no other childhood vaccines were reported as experiencing the same level of hesitancy as the MMR vaccine. Section 1.3.4, *The MMR crisis 1998*, explained how this event increased negative perceptions of the MMR vaccine due to alleged links with autism spectrum disorder.

Although the HPV vaccine is not a childhood vaccine, investigating it further may help to understand why it and the MMR vaccine receive a similar reception. In the umbrella

review, HPV vaccination uptake exhibited similar inverse associations as childhood vaccinations. The HPV vaccine is often referred to as the “cancer vaccine” because it prevents cancers caused by the human papillomavirus, most notably cervical cancer (Gottlieb, 2018). HPV is often sexually transmitted, meaning the vaccine is meant to be administered before sexual activity. Therefore, some parents believe their adolescents do not need to receive this vaccine if they are not sexually active, and equally, receiving it could encourage this behaviour (Gottlieb, 2018).

This demonstrates how not all vaccines are perceived equally, specifically the MMR and HPV vaccines. According to the Socio-ecological Model of Health (see Section 1.2.1, *The Socio-ecological Model of Health and health(care) inequalities*), it could be inferred that vaccination is especially susceptible to the influence of “Community” (E.g., Neighbourhoods, norms, and culture) and “Interpersonal” (Family, friends, and social networks) factors. For instance, some interview participants identified an increase in childhood vaccine hesitancy and “myth-busting” due to the pandemic. As suggested in Section 1.3.3, Vaccine hesitancy, this does not necessarily mean that parents will not get their children vaccinated; it could manifest in a delay or even timely acceptance, but concerns accompany it. The quantitative analysis found more evidence to support lockdown-associated socioeconomic inequalities in MMR vaccination uptake than for the pre-school booster. Childhood vaccination services remained available throughout lockdowns, but concerns about attending GP practices to receive them, an alleged lack of reminders, and more questions regarding vaccinations, were reported (Buck *et al.*, 2023; Skirrow *et al.*, 2022; Skirrow *et al.*, 2021; Skirrow *et al.*, 2024). However, Skirrow *et al.* (2024) emphasised that whilst there was an identified increase in questions about vaccination, this only caused a small minority to mistrust vaccines. This demonstrates that the pandemic did affect childhood vaccinations for both uptake and service delivery.

6.3.4. Education and vaccination knowledge

Moreover, in the umbrella review, systematic review authors often cited lower levels of uptake as being related to socioeconomic position via level of education. The two most frequently cited mechanisms were reduced vaccination knowledge (access to relevant information and/or ability to understand this information) and a lack of confidence (in

vaccination in general or in oneself to make decisions about uptake). As previously discussed, it was suggested that low uptake for disadvantaged socioeconomic groups is related to education via an (allegedly) increased likelihood of health-seeking behaviour. Health-seeking behaviour was identified in the umbrella review, such as researching vaccination, which can have either positive or negative outcomes (see Section 2.8.2, *Understanding the findings*). This was also explored in Theme 4 – Information acquisition, knowledge processes, and balancing informed choice against public health benefits. Interviewees reported lower literacy levels in Deep End NENC GP practices, meaning the vaccination information provided may not be accessible to them.

However, individuals with lower levels of formal education are automatically labelled as uneducated regarding vaccination, thus causing low uptake, unlike those who have spent more time in formal education, which is not linked to low vaccination education but alternative beliefs. This narrative does not reconcile. Sociological theories can be employed to explain this treatment of socioeconomically disadvantaged groups. Such as Lewis (1959), who coined the term “culture of poverty”, which “*focus[es] on the cultural patterns and values that cause poverty...[but this] contributed to the neglect of structural factors and to blaming the poor for their misery*” (Suter, Beycan and Ravazzini, 2017, p. 400).

Although unrelated to socioeconomic position, interviewees suggested that one of the biggest threats to vaccination uptake was low disease awareness. Two participants referred to this as the childhood programme being a “victim” of its own success.

“...in my lifetime, I've seen children going blind, I've seen children being disabled from vaccine preventable diseases, very few parents have. And sometimes I would say that, 'I know this is really, really difficult, but this is what these diseases can do', 'Oh God, I forgot about that!', because you don't see it...” [Public Health Employee 2]

The above quote eloquently summarises this argument – the impact of childhood vaccine-preventable diseases is no longer part of the public consciousness. The wider literature suggests that greater vaccine-preventable disease awareness increases the likelihood of uptake (Maltezou *et al.*, 2020). Still, such awareness is confirmed to be inadequate in the UK (Hilton, Hunt and Petticrew, 2007). One interview participant mentioned that “*there's some patients I know will go on NHS England, and they'll Google*

what they've got wrong with them. Even though they might be chaotic, I know they'll be on NHS.UK." [GP 1] Thus, even patients with "chaotic" personal lives use the internet to investigate their symptoms, but allegedly also have low vaccine-preventable disease awareness.

Low disease awareness is further affected by the rise of social media as information-acquiring processes have shifted (Puri *et al.*, 2020). Skafida and Heins (2024), who explored trust in COVID-19 vaccination information sources, identified that participants who used social media were less likely to take up the vaccine. In the qualitative study, Practice Manager 1 referenced the issue of "*fake news*". Much work has already been published on the role of social media on vaccine uptake, including the additional effect of COVID-19 (Tomassi, Falegnami and Romano, 2024; Clark, Bledsoe and Harrison, 2022; Muric, Wu and Ferrara, 2021; Swaney and Burns, 2019). Some authors refer to this as the "infodemic" (MacDonald, 2020; Farooq and Rathore, 2021; Naeem and Bhatti, 2020; Orso *et al.*, 2020). The infodemic refers to the uncontrolled spread of misinformation and untruths; one route is through social media. It is argued that there has been a shift from Web 1.0, controlled by the provider, to Web 2.0, controlled by the user (Kata, 2012). Anyone with internet access is exposed to a constant stream of information and is equally able to contribute. This means vaccine and vaccination misinformation and untruths can be easily disseminated to a global audience with limited if any, repercussions.

6.3.5. *Is it really all about education? practical barriers to vaccination uptake*

On the other hand, there are issues with persistently associating socioeconomic position with uptake through education via knowledge/information-related mechanisms. For instance, other mechanisms were suggested in the umbrella review, such as accessibility barriers (E.g., transport to vaccination location), albeit less frequently. The causal pathways of other features of socioeconomic position are more difficult to conceptualise.

As previously discussed, the MMR vaccine exhibited the second lowest uptake of all childhood vaccines in the quantitative analysis, but the pre-school booster was the lowest-performing vaccine across all regions. There are two doses of the MMR vaccine

reflected in the uptake statistics, but the pre-school booster reflects only one dose. However, the pre-school booster is exactly as the name implies: a booster of some antigens administered at 2, 3, and 4 months of age as part of the 6-in-1 vaccine (see Section 3.2.2, *The English Childhood vaccination schedule*, for more information). Thus, the priority is for children to receive these previous vaccines before their pre-school booster. If the issue of low uptake solely resided in vaccine hesitancy, it would be expected that uptake of the pre-school booster would outperform the MMR vaccine. This indicates an issue with vaccines that have multiple doses, a factor also identified in the qualitative research. This is further supported by the fact that no additional effects of Phase 1 or Phase 2 COVID-19 vaccination rollout on uptake were identified in the quantitative analysis. If low uptake were related to vaccine mistrust, these events would be expected to further contribute to changes in uptake. Phase 2, especially, coincided with advice from the Joint Committee of Vaccination Immunisation (JCVI) that those under 30 should receive an alternative to the AstraZeneca vaccine, given there was an increased risk of blood clots among this age group. This suggests that access issues may be at play.

The perspectives of childhood programme providers relating to practical issues to uptake were explored in the qualitative interviews, articulated by Theme 3 – Vaccinating the minority: the challenges of delivering the childhood vaccination programme to families from underserved communities. It was suggested that some parents view the schedule as a “*pick ‘n’ mix*” [Public Health Employee 1], thus supporting the argument that the number of doses is a consideration of parents when deciding whether their child should take up the vaccines. Arguably, this could be linked to a lack of awareness of why multiple doses of the same antigen are required. However, service providers believed several other practical issues were barriers for the parents regarding the pre-school booster and MMR2 – E.g., flexibility of appointments and navigating the childcare of their other children. This was a strong message throughout the qualitative component; whilst some parents are vaccine-hesitant, or even “anti-vax”, on many occasions, low uptake results from life barriers. One such group were “chaotic families” or families with “chaotic personal lives”. The term “priorities” was also used by interviewees when discussing the parents' decision to take up vaccinations. Vaccination is considered

primary prevention, administered in the pre-disease phase (see Section 1.3.1, *Preventative healthcare, vaccination*, and immunisation, for more information). Thus, it addresses an issue that does not currently affect their child but could in the future. Parents who perceive their daily concerns as greater than vaccination may prioritise these.

"...coming back to Maslow's Hierarchy, if you've not got the basis of the warm house or roof over your head, you've not got food on the table, then vaccination is not going to be a priority..." [GP 4]

The above quote uses the example of Maslow's hierarchy to articulate the argument. In recent times, there has been an increase in precarious employment, such as zero-hours contracts. Mothers find these circumstances contribute to difficulty with parenting, such as arranging childcare and maintaining a work-life balance (Luhr, Schneider and Harknett, 2022). Fathers were notably absent from the discussion in the qualitative component and the responsibility of ensuring children were vaccinated appeared to reside with the mother. Nevertheless, the increasing difficulty for mothers organising and attending vaccination appointments could speak to wider social issues, such as the cost-of-living crisis.

In the UK, the COVID -19 pandemic and subsequent unforeseen geopolitical factors (E.g., Brexit & Ukraine-Russia War) resulted in a severe economic downturn with gross domestic product (GDP) decreasing by 11.0% in 2020, the sharpest drop since records began and unprecedented in modern times. (Meadows et al., 2024, p. 2)

Subsequently, this has increased the prevalence of deprivation and contributed to declining public health (Meadows et al., 2024). Interview participants expressed how they felt powerless against some of the issues they faced in-practice.

Research suggests tackling health inequalities or "levelling up" needs to be a collaborative strategy (Davey et al., 2022), involving four core factors (Ford et al., 2021, p. e206):

National – E.g., allocation of funding proportionate to need.

System – E.g., redistribution of workforce to support areas most in need.

Organisational – E.g., equity-focused quality improvement programmes or co-production of services.

Individual – E.g., support with welfare claims or reducing implicit bias.

As medical doctors themselves, Singh and Uthayakumar-Cumarasamy (2022) believe the narrative that wider health inequalities cannot be improved from within healthcare provision is misguided. They discuss how these are not solely external processes that healthcare professionals should perceive as beyond their control but simultaneously recognise the pressure the system is experiencing. Suggestions for tackling these inequalities were related to being more mindful when interacting with patients who may face more barriers and consider the “social lens” of their patients (Singh and Uthayakumar-Cumarasamy, 2022). However, as discussed in Section 5.2.3, *The Deep End Network North East and North Cumbria*, the GPs working in Deep End practices experience greater demand for appointments and care for more patients per GP than in less deprived areas, leading to increased levels of stress and burnout (Butler *et al.*, 2022). This relates to the issue of structural violence discussed previously; healthcare provision in deprived areas faces more challenges than elsewhere, and subsequently, providers experience a further decreased capacity to tackle the inequalities faced by their patient populations.

6.3.6. System of dysfunction

The discussion thus far has explored the many complexities in delivering, commissioning, monitoring, and supporting the childhood vaccination programme. Interview participants often felt they were doing all they could to increase uptake, sometimes with little evidential impact. This relates to Theme 5 – What actually works? Addressing the challenges of delivering, commissioning, monitoring, and supporting the childhood vaccination programme.

One approach that appeared to address both vaccine hesitancy and practical barriers to uptake is the health visitor service. Their usefulness in this context was mentioned by fourteen of the fifteen participants. Suggestions of how to overcome vaccine hesitancy were related to the fostering of trust between providers and parents. The umbrella review also identified trust in vaccination providers as a causal mechanism linking socioeconomic position and uptake. Indeed, this is a very common theme in the literature (Abba-Aji *et al.*, 2022; Alabadi *et al.*, 2023; Ames *et al.*, 2017; Cooper *et al.*,

2021; Eve et al., 2018; Ferrer et al., 2014; Harmsen et al., 2013; Karashiali et al., 2023; Larson et al., 2014; Maltezou et al., 2020; Melovic et al., 2020; Muhsen et al., 2012; Muric et al., 2021; Schellenberg and Crizzle, 2020a; Skafida and Heins, 2024; Skirrow et al., 2024; Torracinta et al., 2021b; Williams et al., 2023; Wu et al., 2008).

Health visitors could, once again, be a trusted voice to discuss concerns and vaccinate children when attending homes. This would also remove some access barriers, such as the availability of transport and organising childcare for siblings. It is recognised that integrating this back into the health visitor service is not simple. Health visitors are part of the local authority public health 0-19 Health Child Programme (refer to Section 3.2.1, *The English healthcare system*, for more information). This is separate, therefore, from the NHS England commissioning of the childhood vaccination programme, which creates funding issues. Existing research describes the “detachment” of health visitors from GPs and primary healthcare (Bryar et al., 2017). This is partially due to funding and staffing reductions. Evidence suggested that in 2018, 27% of health visitors were responsible for 500 or more children, more than twice their recommended number (Shimwell, White and Green, 2023). Therefore, whilst this mechanism already exists, significant changes would be required before Health Visitors can accrue more responsibility.

Furthermore, the umbrella review concluded that policies which govern vaccination programmes ultimately affect socioeconomic inequalities in uptake. For instance, decisions regarding the vaccine schedule, location of delivery, and number and timing of doses. In some countries, mandatory policies or mandates are in operation. Mandatory vaccinations mean there are legal repercussions for not vaccinating, which apply to everyone (Vanderslott and Marks, 2021). Vaccine mandates refer to specific policies that prevent access to certain benefits or settings without vaccinations (Vanderslott and Marks, 2021). This relates to the discussion earlier in this chapter, suggesting that lower uptake in higher-income countries amongst high-income groups is linked to an increased sense of agency – specifically in US and Australian contexts (Bryden et al., 2019; Vlasak, Dinero and Roitman, 2023; Swaney and Burns, 2019). The umbrella review identified this association in Germany and the UK (Bocquier et al., 2017). Germany, the US, and Australia operate mandatory vaccination or vaccination mandates (Vanderslott and

Marks, 2021). The UK is the only one of these countries where vaccination is neither mandatory nor are there mandate policies. Thus, the argument that lower uptake for advantaged socioeconomic groups is related to increased agency is unique in the context of the UK. The qualitative component identified that providers and commissioners were not in favour of these policies because “*the big no no is telling people what to do*” [GP 3]. Research suggests that mandatory vaccination is a contentious issue, viewed as a violation of personal rights (Smith, Hodson and Rubin, 2021). One study found that just under 50% of healthcare professionals involved in their interview study did not believe mandates should be introduced in the UK (Mears and Bedford, 2023). This could indicate that the UK population is more resistant to perceived infringements on their vaccination liberties.

Other issues related to the negative impact of vaccination and healthcare policies were referenced in Theme 2 – From policy to practice: the childhood vaccination system and data flows. One motivation for including commissioners in the interview sample was to demonstrate that policies and procedures are often not within the provider's control. GP practices are contracted to provide a service that must abide by certain guidelines, albeit with some flexibility. However, it was suggested by providers and wider vaccination system professionals that some policies in their current form are more problematic than beneficial, such as Quality Outcome Framework (QOF) targets. One participant referred to them as a “perverse disincentive” (refer to Section 3.2.1. *The English healthcare system*, for more information on QOF). QOF was originally introduced to reduce health and funding inequalities (Dixon *et al.*, 2010; Shekelle, 2003). A study exploring the association between socioeconomic deprivation and QOF suggested that this was the case until 2015 when inequality reduction plateaued (Mann, Bracegirdle and Shantikumar, 2023). Authors reported that practices with higher proportions of patients over the age of 65 were associated with greater QOF achievement. It was evident in the interviews that providers in deprived areas felt they had a greater prevalence of younger ill-health than practices in more affluent areas. Although not directly related to vaccination, a practice's finances are directly related to the services and service capacity they can provide. In summary, this demonstrates how policies may contribute to socioeconomic inequalities in childhood vaccination uptake.

6.4. Patient-centred Access to Childhood Vaccination Framework, Version 3

6.4.1. Framework overview

The patient-centred access to vaccination framework was created for the umbrella review. It helped to synthesise the mechanisms that systematic review authors reported contributed to the association between socioeconomic position and routine vaccination uptake. It was then further adapted in Chapter 3, informed by the umbrella review findings and the Socio-ecological Model of Health (refer to Section 3.4.2, *Theory*, Figure 3.1). Thus far, the framework has been solely informed by literature and represented an idealised process of access to vaccination. The following adaptations informed by the mixed methods study ensure it is grounded in primary data collection, thus depicting a more realistic process. The new version of the framework is presented in Figure 6.1. The following section justifies the changes made within each discussion point.

The framework allows stakeholders to identify where significant barriers to childhood vaccination uptake may occur and, by extension, where interventions should be developed and implemented. It also provides an accessible summary of the research project, which can be used in future for briefings for policy and practice partners.

6.4.2. Framework adaptations

The first adaptation to the patient-centred access to vaccination framework was simple but important. Both elements of the thesis (the umbrella review and mixed methods study) identified and confirmed an association exists between socioeconomic position and childhood vaccination and the COVID-19 pandemic, from uptake to in-practice delivery. Thus, to demonstrate the all-encompassing role of societal influences, these now encase the whole system, similar to the Socio-ecological Model (as demonstrated in Section 1.2.1, *The Socio-ecological Model of Health and health(care) inequalities*). This enforces how societal influences affect the whole vaccination system and process while enforcing that they operate beyond their control.

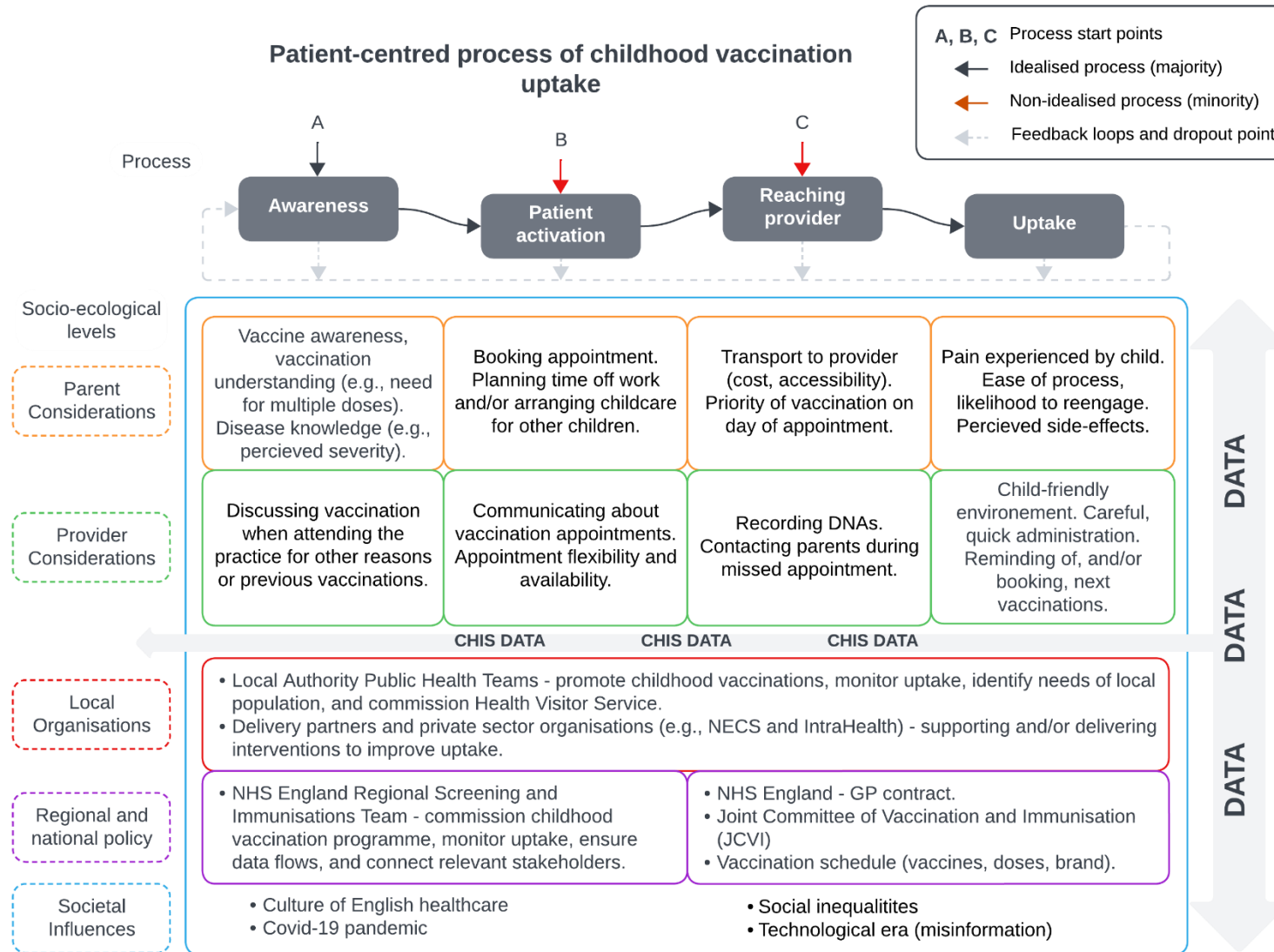
The discussion on education and knowledge informed the second adaptation to the framework. The process of access to vaccination was consolidated; “vaccine policies” and “Vaccine information” were combined into “Awareness”. It was recognised that

although these two stages represent the acquisition of different types of information, they are not necessarily separate. Knowledge of vaccination policies can co-occur with exposure to vaccination information. “Awareness” can encompass many aspects, such as vaccine schedule knowledge, understanding vaccination as a concept, and awareness of diseases. This reconceptualised stage of vaccination is raised, as is “Reaching provider”, to visually portray them as significant “hurdles” in the process.

The third group of adaptations to the patient-centred access to vaccination framework were related to parental autonomy and agency. A core message depicted in Theme 4 was that some parents lack awareness of the vaccine schedule and the need for multiple doses and do not understand the severity of vaccine-preventable diseases. Without this awareness, parents are less proactive in vaccinating their children. This proactivity is now represented by the stage labelled “Patient activation”. The “Patient activation” stage refers to the parent’s responsibility to schedule their child’s vaccination appointment. The “Consenting to vaccination” stage was removed, as appointment attendance is taken as parental consent – as discussed in Section 5.3.6, *Theme 4 – Information acquisition, knowledge processes, and balancing informed choice against public health benefits*.

The final adaption to the third version of the framework emphasises the importance of other organisations and teams – such as the Deep End Network NENC, Local Authority Public Health Teams, and CHIS – in the childhood vaccination programme. An additional level was added to account for the organisations that operate between the provider and national policy. In the interviews, both the Deep End Network NENC and Local Authority Public Health Teams reported organising interventions to support the programme. The latter are also responsible for the health and wellbeing of their child population. Moreover, CHIS teams are key to the entire system. Without accurate data that is able to flow continuously between providers, local organisations, regional teams, and national publications, the system cannot effectively function. Data is required to monitor vaccine uptake and identify where potential outbreaks may occur for public health to prepare. Arrows were added to the framework to illustrate these data flows.

Figure 6.1 A framework conceptualising patient-centred access to childhood vaccination in England, version 3. CHIS = Child Health Information Services.



6.5. Discussion

6.5.1. *The overall message*

This chapter has covered many key debates regarding socioeconomic inequalities in vaccination uptake. In this section, a general commentary on the state of uptake in light of these debates is provided, and the underlying narrative of the thesis is summarised. It has been a continual question as to why vaccination uptake exhibits inverse association in some instances, dissimilar to other healthcare interventions.

The quantitative analysis demonstrated a gradual decline in childhood vaccine uptake for all regions across the study period (2014 – 2022), decreasing by 0.101% (95% CI -0.119% to -0.083%) per quarter for the pre-school booster and 0.089% (95% CI -0.103% to -0.075%) per quarter for the MMR vaccine. However, when modelling further non-linearity in the robustness tests, there was evidence to suggest a statistically significant decline in July – September quarter 2016 (the results are presented in Appendix 4.25). One of the most significant socio-political events around this time was the Brexit referendum in June and the formation of Theresa May’s government in July. The analysis also demonstrated a clear additional decline in pre-school booster and MMR vaccine uptake associated with the first COVID-19 lockdown, but not Phases 1 and 2 COVID-19 vaccination rollout.

Vaccination is inseparable from social processes, such as its entanglement with liberty during the pandemic. Earlier in this chapter, it was discussed that England behaves as if there are mandatory vaccination or vaccination mandates for those administered during childhood. Experts in the field believe introducing mandatory vaccination in England would be “detrimental” to uptake (Elliman and Bedford, 2013). It could be argued that, in England, the uptake of vaccination directly reflects public opinions towards governmental institutions. The most recent British Social Attitudes Survey (BSAS), a longitudinal study that monitors public opinion, identified trust in the Government and the NHS are at an all-time low (Montagu and Maplethorpe, 2024). In 2019, 25% of BSAS reported dissatisfaction with healthcare services; in 2024, this is 52%. The 41st report

cites Brexit, COVID-19, and the Cost-of-Living Crisis as three events which have contributed to this.

This echoes Zygmunt Bauman's theory of liquid modernity (Bauman, 2000). Liquid modernity is categorised by:

"...changing public mood, a waning of the appetite for social reform, a fading interest in the common good and images of the good society, the falling popularity of political engagement, or the rising tide of hedonistic and 'me first' sentiments..." (Bauman, 2000, p. 25)

However, Bauman goes on to suggest that these are only the surface-level manifestations. The underlying premise is that once fixed, solid structures and concepts that dominated modernity are instead fluid and uncertain in the current phase. He claims that this can lead to mistrust in these once-solid structures (Bauman, 2000). Liquid modernity is underpinned by two key processes: individualisation and globalisation (Rattansi, 2017). Although Bauman often discusses these processes from an economic lens, they can be applied elsewhere. Rubeis (2023) coined the term "liquid healthcare" where the use of data to personalise healthcare is simultaneously depersonalising it. The increasing use of technology to improve healthcare means human interaction is decreasing. This directly opposes one of the main methods of increasing uptake related to vaccine hesitancy: trust. On the topic of Bauman's liquid modernity, Abrahamson suggests that,

"...spatial differentiation goes hand in hand with social differentiation. Increasingly, the affluent segments isolate themselves in voluntary ghettos such as gated communities, while the poor are relegated to the enforced ghetto, where they are labelled an underclass and viewed as useless and unwanted..." (Abrahamson, 2004, p. 171)

This identifies with some of the findings of this thesis, namely, that individuals at both ends of the socioeconomic spectrum may behave similarly but are treated differently for it, specifically in discussions of education.

However, this theory has been criticised for exaggerating the disintegration of social structures because they still exist and have not been completely cast aside (Elliott, 2009; Caldwell and Henry, 2020). Thus, all aspects of liquid modernity do not complement this thesis, especially with regard to the Socioecological Model of Health, which emphasises

the interaction between social structures. The application of this theory, therefore, is a softer approach that these structures have not disintegrated but are *disintegrating*.

6.5.2. Implications of findings

The aim of this thesis was as follows:

Aim – To understand and map the narrative and state of socioeconomic inequalities in vaccination uptake in a post-COVID-19 era.

Overall, the results support the existence of socioeconomic inequalities in vaccination uptake, but the association is complex and varying. The umbrella review demonstrated that other countries exhibit similar patterns, especially in high-income settings. The quantitative analysis identified the need for a more nuanced approach to understanding socioeconomic inequalities in vaccination uptake in England. It is not correct to claim there is an overall socioeconomic gradient when the true manifestation is different across regions. The qualitative interviews found the reality of delivering the childhood vaccination programme in areas of high deprivation produced unique challenges that were not recognised in policy.

The discussion suggests that vaccination uptake will continue to decline if public trust does not improve. Current initiatives to improve uptake are only tackling the “symptoms”. This is not to suggest that interventions are ineffective because any child receiving a vaccine is a positive outcome from a public health perspective. However, they are often available for a finite amount of time, rely on unstable/short-term funding, and are offered to a specific group of individuals. There should be a greater shift to scalability and sustainability for long-term success. This will be needed whilst public trust is repaired.

6.6. Recommendations

There are several recommendations as a result of this project. These are separated into academic recommendations, policy recommendations, and in-practice delivery recommendations. Some are more practical and easily implementable, others more ambitious.

6.6.1. Academic recommendations

- Acknowledging the complexity of socioeconomic inequalities in vaccination uptake. Much of the research focuses on education as the link between socioeconomic position and uptake. However, this is not necessarily a helpful discourse as it tends to blame individuals for their position. This narrative is then utilised and synthesised without understanding the mechanisms by which these associations occur. Future research needs to be explicit in how they are operationalising and discussing socioeconomic position. For instance, if “socioeconomic status” is the selected measure, it must be explored what this means and how this may affect uptake through causal mechanisms. This would improve clarity and enable a better understanding of these associations to contribute to an evidential impact on uptake. Although this is an academic recommendation, the implications extend beyond and into policy and practice. Changing the academic narrative can encourage a reframing of the issue at all levels.

6.6.2. Policy recommendations

- Understanding the role of socioeconomic inequalities in vaccination uptake. It is recommended all levels of the system (E.g., regional and local authority) be intimately aware of how socioeconomic inequalities in vaccination uptake manifest in their population. If low uptake is identified in advantaged or disadvantaged areas, interventions should be implemented accordingly. Interventions should take a proportionate universalist approach (see Section 1.2.1, *The Socio-ecological Model of Health and health(care) inequalities*, for more information): “*health actions must be universal, not targeted, but with a scale and intensity that is proportionate to the level of disadvantage*” (Carey, Crammond and De Leeuw, 2015, p. 1).
- Ensuring equitable, not equal, healthcare system funding, especially in a post-COVID-19 context. This recommendation is two-fold: firstly, to ensure funding adequately accounts for the disproportionate challenges faced by providers in areas of high socioeconomic deprivation. It is recognised that deprived areas may

serve more patients per GP, have a greater prevalence of young ill-health, and have patient populations that require more staff input to achieve the same outcomes as less deprived areas. This thesis enforced that, whilst the childhood vaccination programme is an important feature of primary care, it is one of many. Therefore, the recommendation concerns overall funding, not specifically for the childhood vaccination programme. Secondly, the COVID-19 pandemic has contributed to increasing socioeconomic inequalities in health and precarious economic situations. Action must be taken to reverse the trend, and ensuring healthcare is appropriately resourced is paramount.

- Promoting vaccination system collaboration. Discourses of “levelling up” require the involvement of several institutions that work together to enact change, and fragmentation can create more challenges. For example, the “priorities” of vaccination, and the cost-of-living crisis discussion, suggested that reasons for low uptake are intertwined with social security concerns. To address these issues, healthcare and welfare systems must coordinate their efforts to ensure a comprehensive response. To facilitate this collaboration, encouraging the use of the same administrative operating systems may be beneficial. To ensure data transference is accurate and timely, transitioning to administrative systems where this occurs automatically would reduce opportunities for error. If this were adopted nationally, moving child health records from one GP practice and/or CHIS would be more streamlined. The overall benefit of this would be reflected in more accurate COVER statistics used for epidemiological monitoring.

6.6.3. *In-practice delivery recommendations*

- Fostering trusting relationships between parents and their child’s vaccination provider. The role of trust in encouraging vaccination uptake and overcoming hesitancy was a common narrative throughout this thesis. Ensuring families have a named vaccination provider would promote a safe, open environment in which to have these discussions. Nurses could assume this role within GP practices, or vaccination could be reintroduced into the Health Visiting Service. Trust in the government and the NHS is at an all-time low, and it is said to have been impacted

by Brexit and COVID-19. This thesis identified a decline in childhood vaccination uptake around these events. For example, whilst comparatively higher levels of uptake were identified for the North East, there were concerns post-pandemic that the gap was narrowing. Parents must be able to trust providers when they claim vaccination is beneficial to their children, and those around them, to prevent further decline in uptake.

- Personalising patient experience by tailoring provision to their needs. The qualitative component identified that a “one-size-fits-all” approach does not benefit those facing more barriers to accessing vaccination. Several examples could be employed to articulate this recommendation. For instance, online appointment booking tools for childhood vaccinations. Even if this approach only works for some parents, it would free administrative staff to address these patients that require more practice intervention. A second example is recognising that some families may be better served with a drop-in model, where they can attend for their child’s vaccination whenever is appropriate. However, this must be combined with continuity. It is not enough to offer alternative approaches or interventions with no long-term impacts, and it further disadvantages underserved communities that may have begun to rely on them.

6.7. Conclusion

6.7.1. *Strengths and limitations*

The strengths and limitations of the umbrella review and quantitative and qualitative components are discussed in their respective chapters. Therefore, this section will address the strengths and limitations of the mixed methods integration and the thesis as a whole. An exploratory sequential data collection design ensured that the qualitative interviews were guided by the quantitative findings, meaning it was not biased to personal views on what needed to be researched. It offered a unique perspective with a qualitative investigation of childhood vaccination uptake in the North East of England, as research with a regional focus is often conducted in London. The patient-centred access to vaccination framework represents a unifying thread throughout the thesis, adapted first using the umbrella review findings and then informed by the mixed methods

integration. Also, the framework is a visual means of summarising the research, which can be utilised by those delivering, commissioning, supporting, and monitoring the childhood vaccination programme as a tool to pinpoint at what stage of the process interventions are required to increase uptake.

The main limitation of this thesis is that, with the use of the exploratory sequential mixed methods design, it is possible to neglect important information because the quantitative component steers the qualitative. For instance, the quantitative study indicated that the North East had higher uptake levels despite their higher levels of socioeconomic deprivation, and subsequently, the qualitative interviews were conducted in this area. Other regions could offer a different narrative. Due to the reported uniqueness of the North East regarding vaccination uptake and sociodemographic characteristics (see Section 5.1.2, *The North East of England: a brief history*, for more information), the findings from this thesis cannot easily be applied to other areas.

6.7.2. Suggestions for future research

The discourse of socioeconomic inequalities in vaccination uptake has addressed many important facets. However, future research should move away from a focus on the attitudes and opinions of parents on childhood vaccination and instead explore how to improve trust between parents and healthcare providers. This could be done using qualitative methods where both parties would be able to voice their opinions, such as participatory action research. Participatory action research

“...seeks to understand and improve the world by changing it. At its heart is collective, self reflective inquiry that researchers and participants undertake, so they can understand and improve upon the practices in which they participate and the situations in which they find themselves.” (Baum, MacDougall and Smith, 2006, p. 854)

Parents and healthcare providers would be given an opportunity to empathise with one another before proposing solutions or interventions. One of the core features of participatory action research is empowerment (Baum, MacDougall and Smith, 2006). Through co-production, the research will empower and foster trust and create a solution or intervention to promote this.

Another suggestion for future research is further investigation into regional differences in vaccination uptake. This thesis has demonstrated the importance of regional context, especially when analysing socioeconomic factors. A case-study approach could be taken to compare areas with dissimilar vaccination uptake to understand why this may be the case. Quantitative methods could be employed to generate comprehensive area profiles, including demographic and healthcare characteristics. Treating regions as a sum of their parts (local authorities) may offer additional insight. Research questions such as “How do socioeconomic inequalities in vaccination uptake manifest at a granular level across regions?” could be addressed.

6.7.3. *Closing remarks*

This thesis has successfully explored and mapped the narrative and state of socioeconomic inequalities in vaccination uptake in a post-COVID-19 era. Namely, that which is perpetuated in published literature, national uptake statistics, and by professionals who deliver, commission, monitor, and support the childhood vaccination programme. In doing so, it recognises that England is in a precarious position regarding socioeconomic inequalities in childhood vaccination uptake, something which should not be taken lightly.

Appendix 1.1 Table of WHO routine vaccination recommendations (World Health Organization, 2024c).

(updated: April 2024)

Table 1: Summary of WHO Position Papers - Recommendations for Routine Immunization

Antigen		Children (see Table 2 for details)		Adolescents	Adults	Considerations (see footnotes for details)
Recommendations for all immunization programmes						
BCG ¹		1 dose				Birth dose and HIV; Universal vs selective vaccination; Co-administration; Vaccination of older age groups; Pregnancy
Hepatitis B ²		3-4-doses (see footnote for schedule options)		3 doses (for high-risk groups if not previously immunized) (see footnote)		Birth dose Premature and low birth weight Co-administration and combination vaccine Definition high-risk
Polio ³		3-5 doses (at least 2 doses of IPV) with DTPCV				bOPV birth dose; Type of vaccine; Fractional dose IPV; Transmission and importation risk; Local epidemiology, programmatic implications and feasibility for “early” option
DTP-containing vaccine (DTPCV) ⁴		3 doses	2 boosters 12-23 months (DTPCV) and 4-7 years (Td/DT containing vaccine, see footnote)	1 booster 9-15 yrs (Td)		Delayed/interrupted schedule Combination vaccine Maternal immunization
Haemophilus influenzae type b ⁵	Option 1	3 doses, with DTPCV				Single dose if > 12 months of age Not recommended for children > 5 yrs old Delayed/interrupted schedule Co-administration and combination vaccine
	Option 2	2 or 3 doses, with booster at least 6 months after last dose				
Pneumococcal (Conjugate) ⁶	Option 1	3 primary doses (3p+0) with DTPCV				Schedule options (3p+0 vs 2p+1) Vaccine options HIV+ and preterm neonate booster Vaccination in older adults
	Option 2	2 primary doses plus booster dose at 9-18 mos of age (2p+1) with DTPCV				
Rotavirus ⁷		2-3 doses depending on product with DTPCV				Not recommended if > 24 months old
Measles ⁸		2 doses				Co-administration live vaccines; Combination vaccine; HIV early vaccination; Pregnancy
Rubella ⁹		1 dose (see footnote)		1 dose (adolescent girls and women of reproductive age if not previously vaccinated; see footnote)		Achieve and sustain 80% coverage Combination vaccine and Co-administration Pregnancy
HPV ¹⁰				1-2 doses (females)		Target 9-14 year old girls; Off-label 1 dose schedule; MACs with intro; Pregnancy; HIV and immunocompromised

Table 1: Summary of WHO Position Papers - Recommendations for Routine Immunization

Antigen		Children (see Table 2 for details)	Adolescents	Adults	Considerations (see footnotes for details)
Recommendations for certain regions					
Japanese Encephalitis ¹¹		Inactivated Vero cell-derived vaccine: generally 2 doses Live attenuated vaccine: 1 dose Live recombinant vaccine: 1 dose			Co-administration live vaccines; Vaccine options and manufacturer's recommendations; Pregnancy; Immunocompromised
Yellow Fever ¹²		1 dose, with measles containing vaccine			Co-administration live vaccines
Tick-Borne Encephalitis ¹³		3 doses (> 1 yr FSME-Immun and Encepur; > 3 yrs TBE-Moscow and EnceVir) with at least 1 booster dose (every 3 years for TBE-Moscow and EnceVir)			Definition of high-risk Vaccine options Timing of booster
Recommendations for some high-risk populations					
Typhoid ¹⁴		Typhoid conjugate vaccine (Typbar-TCV®): 1 dose; Vi polysaccharide(ViPS): 1 dose; Ty21a live oral vaccine: 3-4 doses (see footnote); Revaccination for ViPS & Ty21a; every 3-7 years			Definition of high-risk Vaccine options
Cholera ¹⁵		Dukoral (WC-rBS): 3 doses ≥ 2-5 yrs, booster every 6 months; 2 doses adults/children ≥ 6 yrs, booster every 2 nd year; Shanchol, Euvchol & mORCVAX: 2 doses ≥1 yrs, booster dose after 2 yrs			Minimum age Definition of high-risk
Meningococcal ¹⁶	MenA conjugate	1 dose 9-18 months (5µg)			2 doses if < 9 months with 8 week interval
	MenC conjugate	2 doses (2-11 months) with booster 1 year after 1 dose (≥12 months)			
	Quadrivalent conjugate	2 doses (9-23 months) 1 dose (≥2 years)			Definition of high-risk; Vaccine options
Hepatitis A ¹⁷		Inactivated: 1 or 2 doses ≥ 12 months		Inactivated: 2 doses if > 40 years of age	Level of endemicity; Vaccine options; Definition of high risk groups
		Live attenuated: 1 dose >18 months of age			
Rabies ¹⁸		2 doses			PrEP vs PEP; definition of high risk; booster
Dengue (CYD-TDV) ¹⁹		3 doses 9-45 years of age			Minimize risk of vaccine among seronegative individuals by pre-vaccination screening;Pregnancy & lactation
Malaria (RTS,S) ²⁰		4 doses			Moderate to high malaria transmission; Strategy for highly seasonal transmission, see notes
Recommendations for immunization programmes with certain characteristics					
Mumps ²¹		2 doses with measles and rubella containing vaccine			High coverage with MR vaccine Combination vaccines
Seasonal influenza (inactivated tri-and quadri-valent) ²²		First vaccine use: 2 doses Revaccinate annually: 1 dose only (see footnote)	1 dose ≥ 9 years of age	Revaccinate annually	Priority risk groups
Varicella ²³		1 - 2 doses	2 doses		Achieve & sustain ≥ 80% coverage Pregnancy Co-administration with other live vaccines

Appendix 2.1 Table of a completed PRISMA-E checklist (Welch *et al.*, 2012).

Checklist of Items for Reporting Equity-Focused Systematic Reviews				
Section	Item	Standard PRISMA Item	Extension for Equity-Focused Reviews	Pg #
Title				
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Identify equity as a focus of the review, if relevant, using the term equity (The term ‘inequalities’ was used)	18
Abstract				
Structured summary	2	2. Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	State research question(s) related to health equity.	N/A
	2A		Present results of health equity analyses (e.g. subgroup analyses or meta-regression).	N/A
	2B		Describe extent and limits of applicability to disadvantaged populations of interest.	N/A
Introduction				
Rationale	3	Describe the rationale for the review in the context of what is already known.	Describe assumptions about mechanism(s) by which the intervention is assumed to have an impact on health equity.	19-22
	3A		Provide the logic model/analytical framework, if done, to show the pathways through which the intervention is assumed to affect health equity and how it was developed.	35-37
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	Describe how disadvantage was defined if used as criterion in the review (e.g. for selecting studies, conducting analyses or judging applicability).	23
	4A		State the research questions being addressed with reference to health equity	23
Methods				
Protocol and	5	Indicate if a review protocol exists, if and where it can be		23

registration		accessed (e.g., Web address), and, if available, provide registration information including registration number.		
Eligibility criteria	6	6. Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	Describe the rationale for including particular study designs related to equity research questions.	25-27
	6A		Describe the rationale for including the outcomes - e.g. how these are relevant to reducing inequity.	25-27
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Describe information sources (e.g. health, non-health, and grey literature sources) that were searched that are of specific relevance to address the equity questions of the review.	30
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Describe the broad search strategy and terms used to address equity questions of the review.	Appendix 2.4
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).		29
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.		30/31
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	List and define data items related to equity, where such data were sought (e.g. using PROGRESS-Plus or other criteria, context).	30/31
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.		32/33
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).		30/31
Synthesis of	14	Describe the methods of handling data and combining	Describe methods of synthesizing findings on health	33-37

results		results of studies, if done, including measures of consistency (e.g., I ²) for each meta-analysis.	inequities (e.g. presenting both relative and absolute differences between groups).	
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).		31/32
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	Describe methods of <u>additional</u> synthesis approaches related to equity questions, if done, indicating which were pre-specified	33-37
Results				
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.		38/39
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Present the population characteristics that relate to the equity questions across the relevant PROGRESS-Plus or other factors of interest.	40-54
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).		40-41
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.		56-67
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Present the results of synthesizing findings on inequities (see 14).	56-67
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).		38
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Give the results of <u>additional</u> synthesis approaches related to equity objectives, if done, (see 16).	63-64
Discussion				
Summary of	24	Summarize the main findings including the strength of		68

evidence		evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).		
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).		72-73
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Present extent and limits of applicability to disadvantaged populations of interest and describe the evidence and logic underlying those judgments.	68-71
	26A		Provide implications for research, practice or policy related to equity where relevant (e.g. types of research needed to address unanswered questions).	71/72
Funding				
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.		15

Appendix 2.2 Detailed inclusion and exclusion criteria for systematic reviews included in the umbrella review.

Inclusion	Exclusion
Access to the full text.	
Reviews published after 2011–September 2022 (present-day – at the time the searches were performed). Any language (interpreters would have been sourced if required).	
Inclusion: Population • All countries. • Normal/general populations. • Any demographic sub-population.	Exclusion: Population - Reviews which focused on: • Occupational sub-populations (E.g., health care workers). • Clinically at-risk populations (E.g., diabetics and pregnant women).
Inclusion: Exposure – Advantaged socioeconomic position - Reviews which focused on: • Socioeconomic position, specifically, education, occupation, income, and area-level deprivation (any operationalisation, E.g., years in education, or primary/secondary).	Exclusion: Exposure • Any other measures of socioeconomic position (E.g., receipt of state benefits, access to clean water, etc.).
Inclusion: Comparison – Disadvantaged socioeconomic position • Socioeconomic position, specifically, education, occupation, income, and area-level deprivation (any operationalisation, E.g., years in education or primary/secondary).	Exclusions: Comparison • Any other measures of socioeconomic position (E.g., receipt of state benefits, access to clean water, etc.).
Inclusion: Outcome - Reviews which focused on: • Vaccine uptake (including either initiation and/or completion for multi-dose vaccines). • Schedule completion. • WHO-recommended routine vaccinations universally or worldwide (World Health, 2021). BCG (Tuberculosis), Hepatitis B, Polio, DTP-containing vaccine (Diphtheria, Tetanus and Pertussis), Haemophilus influenzae type b, Pneumococcal (conjugate), Rotavirus, Measles, Rubella, and HPV (Human papillomavirus).	Exclusion: Outcome - Reviews which focused on: • Interventions to improve vaccine uptake. • Vaccine uptake targets or estimation models. • Timeliness, supplementary immunisation activities (SIAs) or missed opportunities. • WHO vaccine recommendations for certain regions (Japanese Encephalitis, Yellow Fever, Tick-Borne Encephalitis) (World Health, 2021). • WHO vaccine recommendations for some high-risk populations (Typhoid, Cholera, Meningococcal, Hepatitis A,

• Influenza and COVID-19 vaccinations, to account for reviews published in response to the 2019 Coronavirus pandemic. • Single-antigen or combined vaccines (Despite Mumps not being a universally recommended vaccine, it was eligible for inclusion if explored as part of the combined MMR vaccine).	Rabies, and Dengue) (World Health, 2021). • WHO vaccine recommendations for immunisation programs with certain characteristics (Mumps and Varicella) (World Health, 2021).
Inclusion: Study Design • Must be a systematic review, as defined by the DARE criteria (Centre for Reviews and Dissemination, 2014). • Must synthesise primary empirical studies or those which perform secondary analysis on vaccine uptake monitoring data.	Exclusion: Study Design • Studies which state they are reviews but do not meet four or more of the DARE criteria (Centre for Reviews and Dissemination, 2014) or are a primary study or conference paper. • Mixed reviews where the relevant data could not be separated from the irrelevant or erroneous information.

Appendix 2.3 BMJ Knowledge Centre (2022) search string for systematic reviews.

1. review.pt.
2. (medline or medlars or embase or pubmed or cochrane).tw,sh.
3. (scisearch or psychinfo or psycinfo).tw,sh.
4. (psychlit or psyclit).tw,sh.
5. cinahl.tw,sh.
6. ((hand adj2 search\$) or (manual\$ adj2 search\$)).tw,sh.
7. (electronic database\$ or bibliographic database\$ or computeri?ed database\$ or online database\$).tw,sh.
8. (pooling or pooled or mantel haenszel).tw,sh.
9. (peto or dersimonian or der simonian or fixed effect).tw,sh.
10. (retraction of publication or retracted publication).pt.
11. or/2-10
12. 1 and 11
13. meta-analysis.pt.
14. meta-analysis.sh.
15. (meta-analys\$ or meta analys\$ or metaanalys\$).tw,sh.
16. (systematic\$ adj5 review\$).tw,sh.
17. (systematic\$ adj5 overview\$).tw,sh.
18. (quantitativ\$ adj5 review\$).tw,sh.
19. (quantitativ\$ adj5 overview\$).tw,sh.
20. (quantitativ\$ adj5 synthesis\$).tw,sh.
21. (methodologic\$ adj5 review\$).tw,sh.
22. (methodologic\$ adj5 overview\$).tw,sh.
23. (integrative research review\$ or research integration).tw.
24. or/13-23
25. 12 or 24

Appendix 2.4 Table of pilot search results.

	Study Design	
1	review.pt.	2987245
2	(medline or medlars or embase or pubmed or cochrane).tw,sh.	296414
3	(scisearch or psychinfo or psycinfo).tw,sh.	49246
4	(psychlit or psyclit).tw,sh.	914
5	cinahl.tw,sh.	37808
6	((hand adj2 search\$) or (manual\$ adj2 search\$)).tw,sh.	15423
7	(electronic database\$ or bibliographic database\$ or computeri?ed database\$ or online database\$).tw,sh.	50629
8	(pooling or pooled or mantel haenszel).tw,sh.	132062
9	(peto or dersimonian or der simonian or fixed effect).tw,sh.	9513
10	(retraction of publication or retracted publication).pt.	23482
11	or/2-10	456683
12	1 and 11	194331
13	meta-analysis.pt.	165901
14	meta-analysis.sh.	165901
15	(meta-analys\$ or meta analys\$ or metaanalys\$).tw,sh.	266288
16	(systematic\$ adj5 review\$).tw,sh.	279585
17	(systematic\$ adj5 overview\$).tw,sh.	3089
18	(quantitativ\$ adj5 review\$).tw,sh.	9665
19	(quantitativ\$ adj5 overview\$).tw,sh.	383
20	(quantitativ\$ adj5 synthesis\$).tw,sh.	3915
21	(methodologic\$ adj5 review\$).tw,sh.	7738
22	(methodologic\$ adj5 overview\$).tw,sh.	519
23	(integrative research review\$ or research integration).tw.	162
24	or/13-23	424115
25	12 or 24	500272
	Population	
26	exp socioeconomic factors/ or sociodemographic factors/	494165
27	(socioeconomic or socio-economic or sociodemographic or sep or ses or class).mp.	838465
28	education/	21502
29	(education or lifelong learning or life-long learning or human capital or school* or literacy or academic achievement).mp.	1257312
30	work/	20242
31	(employ* or unemploy* or occupation* or job* or work or career* or vocation or economic activity or labour market activity or isco).mp.	2227277
32	(income or wealth or wage* or salar* or earning* or low-income or money).mp.	246861
33	((inequit* or inequalit* or unequal or equal* or equit* or depriv* or poverty or impoverished or disadvantage* or gradient or gap* or disparit* or difference*) adj3 economic).mp.	7627

34	26 or 27 or 28 or 29 or 30 or 31 or 32 or 33	4120827
	Intervention	
35	Injections/ or tuberculosis Vaccines/ or Hepatitis B Vaccines/ or Pertussis Vaccines/ or exp Diphtheria Toxoid/ or Tetanus Toxoid/ or Haemophilus Vaccines/ or exp poliovirus vaccines/ or exp Pneumococcal vaccines/ or rotavirus vaccines/ or exp measles vaccine/ or rubella vaccine/ or exp papillomavirus vaccines/ or influenza vaccines/ or exp COVID-19 vaccines	147148
36	(vaccine* or immunize or immunise or injection* or jab* or inoculate).mp.	1137349
37	((tb or tuberculosis or Hep B or Hepatitis B or diphtheria or tetanus or pertussis or whooping cough or hib or haemophilus or haemophilus influenzae type b or poliovirus or polio or poliomyelitis or pneumococcal or pneumococcus or rotavirus or measles or rubella or human papillomavirus or wart virus or influenza or flu or COVID-19 or COVID 19 or COVID19 or coronavirus or SARS-CoV-2 or SARS Cov 2 or severe acute respiratory syndrome) adj3 vaccine*).mp.	116029
38	((BCG or HepB or IPV or DTP-containing or DTPCV or Td or DT or DTaP or Tdap or PCV or PPV or RV or MMR or MR or HPV or IIV or LAIV) adj3 vaccine*).mp.	35403
39	35 or 36 or 37 or 38	1143673
40	25 AND 34 AND 39	2087

	Study Design	
1	review.pt.	2987245
2	(medline or medlars or embase or pubmed or cochrane).tw,sh.	296414
3	(scisearch or psychinfo or psycinfo).tw,sh.	49246
4	(psychlit or psyclit).tw,sh.	914
5	cinahl.tw,sh.	37808
6	((hand adj2 search\$) or (manual\$ adj2 search\$)).tw,sh.	15423
7	(electronic database\$ or bibliographic database\$ or computeri?ed database\$ or online database\$).tw,sh.	50629
8	(pooling or pooled or mantel haenszel).tw,sh.	132062
9	(peto or dersimonian or der simonian or fixed effect).tw,sh.	9513
10	(retraction of publication or retracted publication).pt.	23482
11	or/2-10	456683
12	1 and 11	194331
13	meta-analysis.pt.	165901
14	meta-analysis.sh.	165901
15	(meta-analys\$ or meta analys\$ or metaanalys\$).tw,sh.	266288
16	(systematic\$ adj5 review\$).tw,sh.	279585
17	(systematic\$ adj5 overview\$).tw,sh.	3089
18	(quantitativ\$ adj5 review\$).tw,sh.	9665
19	(quantitativ\$ adj5 overview\$).tw,sh.	383
20	(quantitativ\$ adj5 synthesis\$).tw,sh.	3915
21	(methodologic\$ adj5 review\$).tw,sh.	7738
22	(methodologic\$ adj5 overview\$).tw,sh.	519

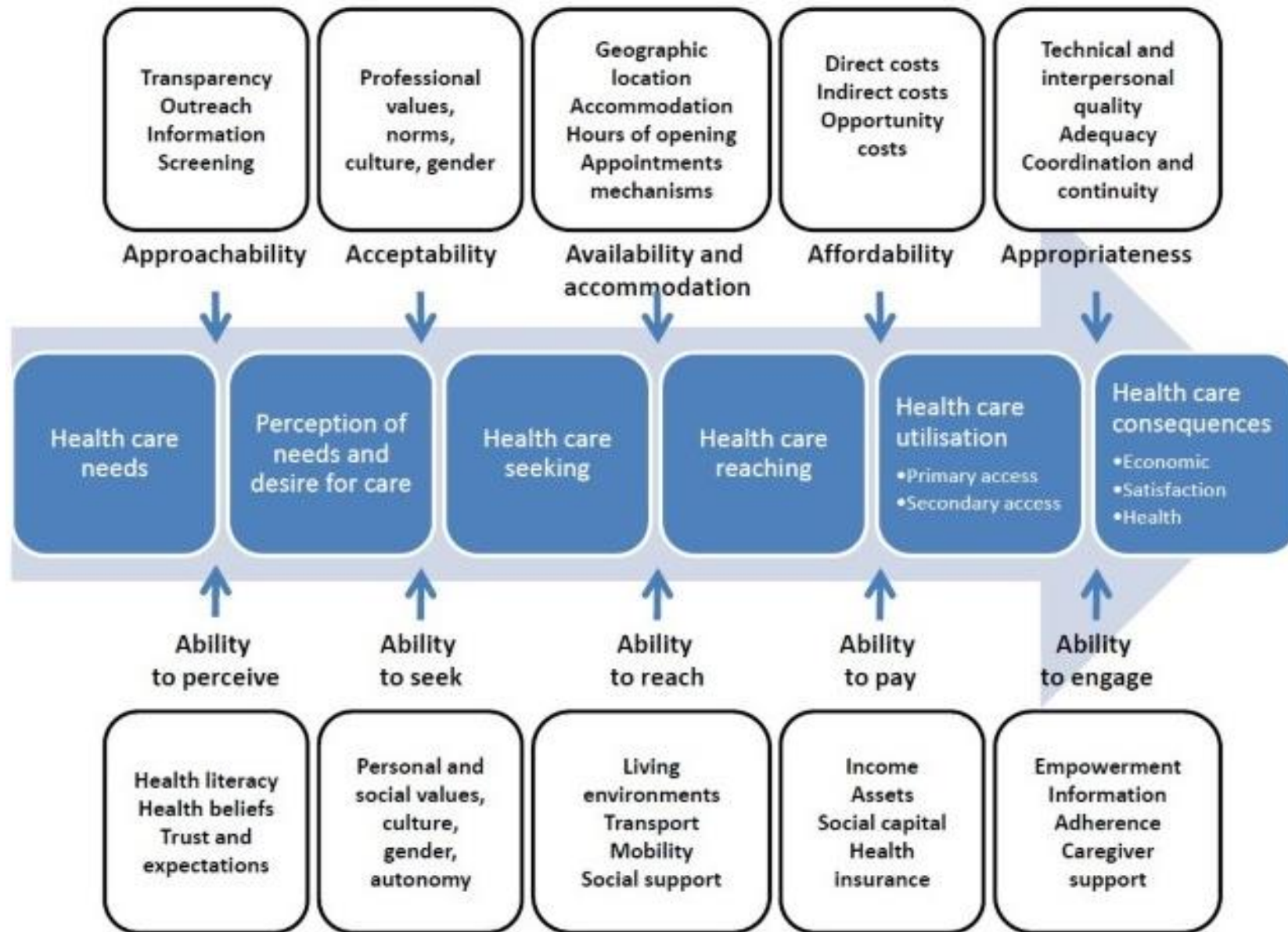
23	(integrative research review\$ or research integration).tw.	162
24	or/13-23	424115
25	12 or 24	500272
	Population	
26	exp socioeconomic factors/ or sociodemographic factors/	494165
27	(socioeconomic or socio-economic or sociodemographic or sep or ses or class).mp.	838465
28	education/	21502
29	(education or lifelong learning or life-long learning or human capital or school* or literacy or academic achievement).mp.	1257312
30	work/	20242
31	(employ* or unemploy* or occupation* or job* or work or career* or vocation or economic activity or labour market activity or isco).mp.	2227277
32	(income or wealth or wage* or salar* or earning* or low-income or money).mp.	246861
33	((inequit* or inequalit* or unequal or equal* or equit* or depriv* or poverty or impoverished or disadvantage* or gradient or gap* or disparit* or difference*) adj3 economic).mp.	7627
34	26 or 27 or 28 or 29 or 30 or 31 or 32 or 33	4120827
	Intervention	
35	Injections/ or tuberculosis Vaccines/ or Hepatitis B Vaccines/ or Pertussis Vaccines/ or exp Diphtheria Toxoid/ or Tetanus Toxoid/ or Haemophilus Vaccines/ or exp poliovirus vaccines/ or exp Pneumococcal vaccines/ or rotavirus vaccines/ or exp measles vaccine/ or rubella vaccine/ or exp papillomavirus vaccines/ or influenza vaccines/ or exp COVID-19 vaccines	147148
36	(vaccine* or immunize or immunise or injection* or jab* or inoculate).mp.	1137349
37	((tb or tuberculosis or Hep B or Hepatitis B or diphtheria or tetanus or pertussis or whooping cough or hib or haemophilus or haemophilus influenzae type b or poliovirus or polio or poliomyelitis or pneumococcal or pneumococcus or rotavirus or measles or rubella or human papillomavirus or wart virus or influenza or flu or COVID-19 or COVID 19 or COVID19 or coronavirus or SARS-CoV-2 or SARS Cov 2 or severe acute respiratory syndrome) adj3 vaccine*).mp.	116029
38	((BCG or HepB or IPV or DTP-containing or DTPCV or Td or DT or DTaP or Tdap or PCV or PPV or RV or MMR or MR or HPV or IIV or LAIV) adj3 vaccine*).mp.	35403
39	35 or 36 or 37 or 38	1143673
40	25 AND 34 AND 39	2087
	Outcome	
41	exp vaccination/ or exp vaccination hesitancy/ or vaccination coverage/	102709
42	(vaccination or immunization or immunization or inoculation or uptake or coverage or rate* or accept* or hesitan* or access).mp.	4987546
43	41 or 42	4987546
44	40 AND 43	1282
45	limit 44 to yr="2011 -Current"	1090

Appendix 2.5 Synthesis Without Meta-analysis recommendations, which uses a 9-item checklist (Mhairi *et al.*, 2020, pp. 2-5)

SWiM reporting item	Item description	Page No.
Methods		
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (eg, groupings of populations, interventions, outcomes, study design)	33-37
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	72/73
2 Describe the standardised metric and transformation methods used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance consulted	33-37
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates	33-37
4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select the particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (eg, based on study design, risk of bias assessments, directness in relation to the review question)	N/A
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it was not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity	31/32
6 Certainty of evidence	Describe the methods used to assess the certainty of the synthesis findings	32/33
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (eg, tables, forest plots, harvest plots)	33-37
	Specify key study characteristics (eg, study design, risk of bias) used to order the studies, in the text and any tables or graphs, clearly referencing the studies included	
Results		
8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis	55-67
Discussion		
9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis and how these affect the	72/73

	conclusions that can be drawn in relation to the original review question	
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Appendix 2.6 Levesque *et al.*'s (2013) patient-centred access to healthcare framework.



Appendix 2.7 Illustrates a framework (version 1) depicting the access to vaccination and the considerations of the individual and vaccination provider at each stage. Adapted from Levesque *et al.*'s (2013) patient-centred access to healthcare framework, in table form.

	Mediators	Explanation	Mechanism	Reference
A ↓	Approachability	“Correct, unbiased information provided about vaccines and vaccination.”		
	Ability/likelihood to approach	“Health literacy and beliefs and trust in the benefits of vaccines and vaccination.”		
B ↓	Acceptability	“Integrity, outward presentation of vaccine manufacturers and vaccination provider.”		
	Ability/likelihood to accept	“Personal, social, and cultural attitudes towards vaccine and vaccination.”		
C ↓	Accessibility	“Geographic location and opening times of vaccination provider.”		
	Ability/likelihood to access	“Perceived quality of vaccination provider. Transport to vaccination provider location.”		
D ↓	Affordability	“Direct, indirect, and opportunity costs of vaccines and vaccination programmes.”		
	Ability/likelihood to pay	“Method of payment (insurance, taxation, out-of-pocket).”		
E ↓	Affects	“Service satisfaction. Reducing the impact or occurrence of VPD.”		
	Likelihood of positive affects	“Protection against vaccine-preventable diseases. Positive experience.”		

Appendix 2.8 Table of exclusion reasons for identified but ineligible reviews.

Title	Year	Authors	Notes	
The Factors That Promote Vaccine Hesitancy, Rejection, or Delay in Parents	2020	Majid Umair and Ahmad Mobeen	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Human Papillomavirus Infection and Vaccination	2016	Valentino, Katie and Poronsky, Cathlin B	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Public attitudes and influencing factors toward COVID-19 vaccination for adolescents/children: a scoping review	2022	Liu, Y and Ma, Q and Liu, H and Guo, Z	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Factors that influence parents' and informal caregivers' views and practices regarding routine childhood vaccination: a qualitative evidence synthesis	2021	Cooper, S and Schmidt, B-M and Sambala, EZ and Swartz, A and Colvin, CJ and Leon, N and Wiysonge, CS	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Barriers and facilitators to HPV vaccination of young women in high-income countries: A qualitative systematic review and evidence synthesis	2014	Ferrer, Harriet Batista and Trotter, Caroline and Hickman, Matthew and Audrey, Suzanne	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
"Hpv? Never heard of it!": a systematic review of girls' and parents' information needs, views and preferences about human papillomavirus vaccination	2013	Hendry, Maggie and Lewis, Ruth and Clements, Alison and Damery, Sarah and Wilkinson, Clare	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Defining the determinants of vaccine uptake and undervaccination in migrant populations in Europe to improve routine and COVID-19 vaccine uptake: a systematic review	2022	Crawshaw A.F. and Farah Y. and Deal A. and Rustage K. and Hayward S.E. and Carter J. and Knights F. and Goldsmith L.P. and Campos-Matos I. and Wurie F. and Majeed A. and Bedford H. and Forster A.S. and Hargreaves S.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome

Factors affecting poor measles vaccination coverage in sub-Saharan Africa with a special focus on Nigeria: a narrative review	2022	Majekodunmi O.B. and Oladele E.A. and Greenwood B.	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
Prevalence and Determinants of COVID-19 Vaccine Hesitancy Among the Ethiopian Population: A Systematic Review	2022	Yehualashet D.E. and Seboka B.T. and Tesfa G.A. and Mamo T.T. and Yawo M.N. and Hailegebreal S.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Determinants of COVID-19 vaccine acceptance in Ethiopia: A systematic review and meta-analysis	2022	Mose A. and Wasie A. and Shitu S. and Haile K. and Timerga A. and Melis T. and Sahle T. and Zewdie A.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
COVID-19 Vaccine Acceptance among Low- and Lower-Middle-Income Countries: A Rapid Systematic Review and Meta-Analysis	2022	Patwary M.M. and Alam M.A. and Bardhan M. and Disha A.S. and Haque M.Z. and Billah S.M. and Kabir M.P. and Browning M.H.E.M. and Rahman M.M. and Parsa A.D. and Kabir R.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Acceptance of COVID-19 Vaccine and Its Associated Factors Among Ethiopian Population: A Systematic Review	2022	Bayou F.D. and Amare S.N.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Impact of COVID-19 pandemic on routine vaccination coverage of children and adolescents: A systematic review	2022	SeyedAlinaghi S. and Karimi A. and Mojdeganlou H. and Alilou S. and Mirghaderi S.P. and Noori T. and Shamsabadi A. and Dadras O. and Vahedi F. and Mohammadi P. and Shojaei A. and Mahdiabadi S. and Janfaza N. and Keshavarzpoor Lonbar A. and Mehraeen E. and Sabatier J.-M.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Improving the Acceptability of Human Papillomavirus Vaccines Among Men Who Have Sex With Men According to the Associated Factors: A Systematic Review and Meta-analysis	2021	Zhao Y. and Xin X. and Deng H. and Xu J. and Weng W. and Zhang M. and Li J. and Gao Y. and Huang X. and Liu C.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome

Acceptance of COVID-19 vaccination and correlated variables among global populations: A systematic review and meta-analysis	2021	Nindrea R.D. and Usman E. and Katar Y. and Sari N.P.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Factors associated with the hpv vaccination among korean americans and koreans: A systematic review	2022	Jo S. and Han S.-Y. and Walters C.A.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Progress and barriers towards maternal and neonatal tetanus elimination in the remaining 12 countries: a systematic review	2021	Yusuf N. and Raza A.A. and Chang-Blanc D. and Ahmed B. and Hailegebriel T. and Luce R.R. and Tanifum P. and Masresha B. and Faton M. and Omer M.D. and Farrukh S. and Aung K.D. and Scobie H.M. and Tohme R.A.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Global COVID-19 Vaccine Acceptance: A Systematic Review of Associated Social and Behavioral Factors	2022	Shakeel C.S. and Mujeeb A.A. and Mirza M.S. and Chaudhry B. and Khan S.J.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
HPV vaccine: uptake and understanding among global Indigenous communities - a qualitative systematic review	2021	Poirier B. and Sethi S. and Garvey G. and Hedges J. and Canfell K. and Smith M. and Ju X. and Jamieson L.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Vaccination uptake amongst older adults from minority ethnic backgrounds: A systematic review	2021	Bhanu C. and Gopal D.P. and Walters K. and Chaudhry U.A.R.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Hepatitis B vaccination coverage in Germany: systematic review	2021	Steffen G. and Sperle I. and Harder T. and Sarma N. and Beermann S. and Thamm R. and Bremer V. and Zimmermann R. and Dudareva S.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Disruptions to routine childhood vaccinations in low- and middle-income countries during the COVID-19 pandemic: A systematic review.	2022	Cardoso Pinto, Alexandra M and Ranasinghe, Lasith and Dodd, Peter J and Budhathoki, Shyam Sundar and Seddon, James A and Whittaker, Elizabeth	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome

Covid-19 Vaccine Acceptance and Determinant Factors among General Public in East Africa: A Systematic Review and Meta-Analysis.	2022	Alemayehu, Astawus and Demissie, Abebaw and Yusuf, Mohammed and Gemechu Lencha, Abebe and Oljira, Lemessa	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Ethnic/racial minorities' and migrants' access to COVID-19 vaccines: A systematic review of barriers and facilitators.	2022	Abba-Aji, Mohammed and Stuckler, David and Galea, Sandro and McKee, Martin	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Attitudes, acceptance and hesitancy among the general population worldwide to receive the COVID-19 vaccines and their contributing factors: A systematic review.	2021	Cascini, Fidelia and Pantovic, Ana and Al-Ajlouni, Yazan and Failla, Giovanna and Ricciardi, Walter	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Human papillomavirus vaccination uptake in low-and middle-income countries: a meta-analysis.	2021	Dorji, Thinley and Nopsopon, Tanawin and Tamang, Saran Tenzin and Pongpirul, Krit	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
The impact of the COVID-19 pandemic on immunization campaigns and programs: A systematic review	2021	Lassi Z.S. and Naseem R. and Salam R.A. and Siddiqui F. and Das J.K.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Vaccination against COVID-19: A systematic review and meta-analysis of acceptability and its predictors	2021	Wang Q. and Yang L. and Jin H. and Lin L.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
A scoping review to find out worldwide covid-19 vaccine hesitancy and its underlying determinants	2021	Biswas M.R. and Alzubaidi M.S. and Shah U. and Abd-Alrazaq A.A. and Shah Z.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
A rapid systematic review of factors influencing covid-19 vaccination uptake in minority ethnic groups in the uk	2021	Kamal A. and Hodson A. and Pearce J.M.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome

[Human papillomavirus vaccine receptivity: a systematic reviewreceptividad con respecto a la vacuna contra el virus del papiloma humano: revision sistematica].	2019	da Silva, Lidia Ester Lopes and de Oliveira, Maria Liz Cunha and Galato, Dayani	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
COVID-19 vaccine hesitancy in Africa: a scoping review.	2022	Ackah, Betty B B and Woo, Michael and Stallwood, Lisa and Fazal, Zahra A and Okpani, Arnold and Ukah, Ugochinyere Vivian and Adu, Prince A	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
What is the state-of-the-art in clinical trials on vaccine hesitancy 2015-2020?	2021	Pires C.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Vaccine attitudes among young adults in Asia: a systematic review	2021	Wang L. and Liang Y. and Zhang X. and Yang J.	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
Evaluation of the Acceptance Rate of Covid-19 Vaccine and its Associated Factors: A Systematic Review and Meta-analysis.	2022	Kazeminia, Mohsen and Afshar, Zeinab Mohseni and Rajati, Mojgan and Saeedi, Anahita and Rajati, Fatemeh	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Mmr vaccine attitude and uptake research in the united kingdom: A critical review	2021	Torracinta L. and Tanner R. and Vanderslott S.	RAYYAN-EXCLUSION-REASONS: not a systematic review, as defined by DARE	Wrong study design
COVID-19 vaccination hesitancy in Hispanics and African-Americans: A review and recommendations for practice.	2021	Khubchandani, Jagdish and Macias, Yilda	RAYYAN-EXCLUSION-REASONS: focus on hesitancy	Wrong outcome
Barriers and facilitators to HPV vaccine uptake among US rural populations: a scoping review	2020	Peterson C.E. and Silva A. and Holt H.K. and Balanean A. and Goben A.H. and Dykens J.A.	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
Predictors of COVID-19 Vaccine Acceptance, Intention, and Hesitancy: A Scoping Review.	2021	Joshi, Ashish and Kaur, Mahima and Kaur, Ritika and Grover, Ashoo and Nash, Denis and El-Mohandes, Ayman	RAYYAN-EXCLUSION-REASONS: focus on hesitancy	Wrong outcome

Barriers to childhood immunization in sub-Saharan Africa: A systematic review	2020	Bangura J.B. and Xiao S. and Qiu D. and Ouyang F. and Chen L.	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
Vaccine acceptability, uptake and completion amongst men who have sex with men: A systematic review, meta-analysis and theoretical framework.	2021	Nadarzynski, Tom and Frost, Miles and Miller, Danny and Wheldon, Christopher W and Wiernik, Brenton M and Zou, Huachun and Richardson, Daniel and Marlow, Laura A V and Smith, Helen and Jones, Christina J and Llewellyn, Carrie	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Analysis of community-based studies related with knowledge, awareness, attitude, and behaviors towards hpv and hpv vaccine published in turkey: A systematic review	2020	Ozdemir S. and Akkaya R. and Karasahin K.E.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Barriers to vaccination in Latin America: A systematic literature review	2020	Guzman-Holst A. and DeAntonio R. and Prado-Cohrs D. and Juliao P.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Vaccine-preventable diseases and immunisation coverage among migrants and non-migrants worldwide: A scoping review of published literature, 2006 to 2016.	2019	Charania, Nadia A and Gaze, Nina and Kung, Janice Y and Brooks, Stephanie	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
Determinants of Seasonal Influenza Vaccine Uptake Among the Elderly in the United States: A Systematic Review and Meta-Analysis	2019	Okoli G.N. and Abou-Setta A.M. and Neilson C.J. and Chit A. and Thommes E. and Mahmud S.M.	RAYYAN-EXCLUSION-REASONS: Old review, updated version included	Outdated review
Acceptance and uptake of influenza vaccines in Asia: A systematic review	2019	Sheldenkar A. and Lim F. and Yung C.F. and Lwin M.O.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome

Measles Status-Barriers to Vaccination and Strategies for Overcoming Them.	2018	Storr, Constanze and Sanftenberg, Linda and Schelling, Joerg and Heininger, Ulrich and Schneider, Antonius	RAYYAN-EXCLUSION-REASONS: not a systematic review, as defined by DARE	Wrong study design
Ensuring childhood vaccination among slums dwellers under the National Immunization Program in India - Challenges and opportunities.	2018	Singh, Sanjeev and Sahu, Damodar and Agrawal, Ashish and Vashi, Meeta Dhaval	RAYYAN-EXCLUSION-REASONS: not a systematic review, as defined by DARE	Wrong study design
Health literacy and vaccination: A systematic review.	2018	Lorini, Chiara and Santomauro, Francesca and Donzellini, Martina and Capecchi, Leonardo and Bechini, Angela and Boccalini, Sara and Bonanni, Paolo and Bonaccorsi, Guglielmo	RAYYAN-EXCLUSION-REASONS: wrong outcome	Wrong outcome
Facilitators and barriers for use of rotavirus vaccine amongst various stakeholders and its implications for Indian context-A systematic review	2018	Apte A. and Roy S. and Bavdekar A. and Juvekar S. and Hirve S.	RAYYAN-EXCLUSION-REASONS: focus on intention to vaccinate	Wrong outcome
Knowledge, awareness and acceptability of anti-hpv vaccine in the arab states of the middle east and north africa region: A systematic review	2018	Gamaoun R.	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Coverage and determinants of childhood immunization in Nigeria: A systematic review and meta-analysis.	2017	Adeloye, Davies and Jacobs, Wura and Amuta, Ann O and Ogundipe, Oluwatomisin and Mosaku, Oluwaseun and Gadanya, Muktar A and Oni, Gbolahan	RAYYAN-EXCLUSION-REASONS: wrong outcome	Wrong outcome
Human Papillomavirus Vaccination Uptake in Canada: A Systematic Review and Meta-analysis.	2017	Bird, Yelena and Obidiya, Olatunji and Mahmood, Razi and Nwankwo, Chijioke and Moraros, John	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
Determinants of European parents' decision on the vaccination of their children against measles, mumps and rubella: A systematic review and meta-analysis.	2016	Tabacchi, Garden and Costantino, Claudio and Napoli, Giuseppe and Marchese, Valentina and Cracchiolo, Manuela and	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot	Wrong outcome

		Casuccio, Alessandra and Vitale, Francesco and The Esculapio Working Group	be separated from the irrelevant	
Immunisation coverage in rural-urban migrant children in low and middle-income countries (Imics): a systematic review and meta-analysis.	2016	Awoh, Abiyemi Benita and Plugge, Emma	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
Gender Determinants of Vaccination Status in Children: Evidence from a Meta-Ethnographic Systematic Review.	2015	Merten, Sonja and Martin Hilber, Adriane and Biaggi, Christina and Secula, Florence and Bosch-Capblanch, Xavier and Namgyal, Pem and Hombach, Joachim	RAYYAN-EXCLUSION-REASONS: does not report vaccine uptake	Wrong outcome
Antimeningococcal and antipneumococcal vaccination determinants: a European systematic literature review.	2015	Malerba, Valentina and Costantino, Claudio and Napoli, Giuseppe and Marchese, Valentina and Casuccio, Alessandra and Tabacchi, Garden and Vitale, Francesco and ESCULAPIOWorking Group and Amicizia D, Bechini A, Boccacini S, Bonanni P, Coppola R, Fortunato F, Gasparini R, Levi M, Martinelli D, Panatto D, Pellizzari B, Prato R	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
HPV vaccine acceptability in Africa: a systematic review.	2014	Cunningham, Melissa S and Davison, Colleen and Aronson, Kristan J	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Facilitators and barriers to adult vaccination in south east asia and Latin America	2017	Davis B.M. and Black D.	RAYYAN-EXCLUSION-REASONS: conference abstract	Wrong study design
Reducing social inequalities in childhood vaccination uptake	2017	Uhomoibhi C. and Bedford H. and Pearce A.	RAYYAN-EXCLUSION-REASONS: wrong outcome	Wrong outcome
Immunization, urbanization and slums - a systematic review of factors and interventions	2017	Crocker-Buque T. and Mindra G. and Duncan R. and Mounier-Jack S.	RAYYAN-EXCLUSION-REASONS: Mixed reviews: relevant information cannot be separated from the irrelevant	Wrong outcome

Vaccinations in migrants and refugees: a challenge for European health systems. A systematic review of current scientific evidence	2017	Mipatrini D. and Stefanelli P. and Severoni S. and Rezza G.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
HPV vaccine acceptability among men: a systematic review and meta-analysis.	2013	Newman, Peter A and Logie, Carmen H and Doukas, Nick and Asakura, Kenta	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Inequity in childhood immunization in India: a systematic review.	2012	Mathew, Joseph L	RAYYAN-EXCLUSION-REASONS: not a systematic review, as defined by DARE	Wrong study design
Reasons related to non-vaccination and under-vaccination of children in low and middle income countries: findings from a systematic review of the published literature, 1999-2009.	2011	Rainey, Jeanette J and Watkins, Margaret and Ryman, Tove K and Sandhu, Paramjit and Bo, Anne and Banerjee, Kaushik	RAYYAN-EXCLUSION-REASONS: contains intervention studies	Wrong outcome
Factors affecting the uptake of vaccination by the elderly in Western society	2014	Eilers R. and Krabbe P.F.M. and de Melker H.E.	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Reasons given for non-vaccination, under-vaccination and delayed vaccination of children and adolescents in sub-Saharan Africa: a systematic review		Lauren Perieres, Valerie Seror, Patrick Peretti-Watel, Sylvie Boyer, Cheikh Sokhna	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
Mapping global acceptance of COVID-19 vaccine: a systematic review and meta-analysis		Qian Wang, Simeng Hu, Fanxing Du, Shujie Zang, Yuting Xing, Xu Zhang, Zhiqiang Qu, Zhiyuan Hou	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
COVID-19 vaccine acceptance and its associated factors in Ethiopia: a systematic review and meta-analysis		Birye Dessalegn Mekonnen, Banchigizie Adane Mengistu	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome

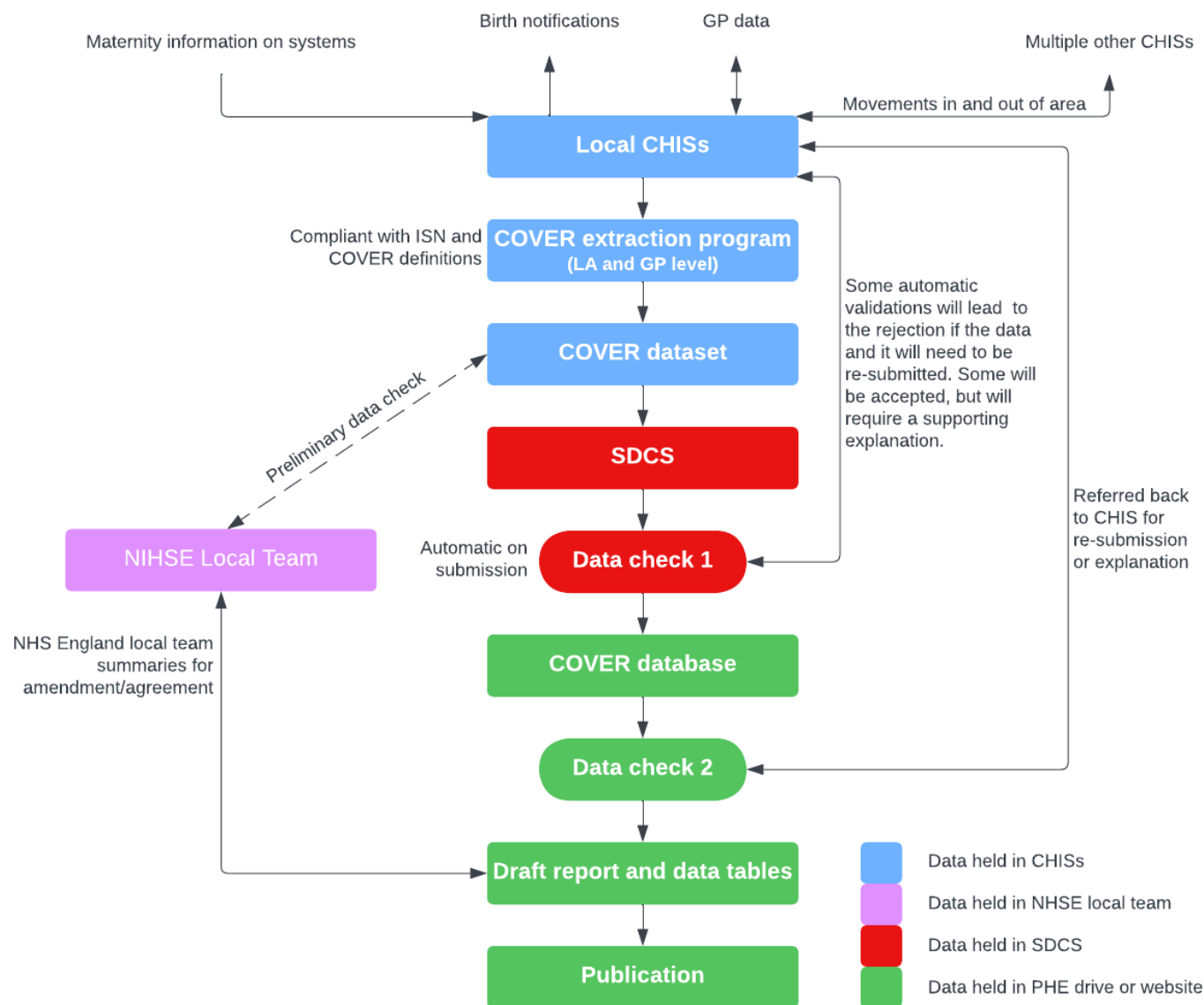
Systematic review and meta-analysis of COVID-19 vaccination acceptance		Ruhana Che Yusof, Norhayati Mohd Noor, Mohd Azman Yacob	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Vaccine Hesitancy: Where We Are and Where We Are Going	2017	McClure, CC and Cataldi, JR and O'Leary, ST	RAYYAN-EXCLUSION-REASONS: not a systematic review, as defined by DARE	Wrong study design
The Uptake of Human Papillomavirus (HPV) Vaccine Among Adolescent Females in the United States: A Review of the Literature	2011	Bartlett, JA and Peterson, JA	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
A rapid review of evidence on the determinants of and strategies for COVID-19 vaccine acceptance in low- and middle-income countries	2021	Moola, S and Gudi, N and Nambiar, D and Dumka, N and Ahmed, T and Sonawane, IR and Kotwal, A	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome
Parents' Decisions to Vaccinate Children against COVID-19: A Scoping Review	2021	Pan, FM and Zhao, HY and Nicholas, S and Maitland, E and Liu, RG and Hou, QZ	RAYYAN-EXCLUSION-REASONS: does not report vaccine uptake	Wrong outcome
Human Papillomavirus Vaccine Uptake in Adolescent Boys: An Evidence Review	2016	Voss, DS and Wofford, LG	RAYYAN-EXCLUSION-REASONS: not a systematic review, as defined by DARE	Wrong study design
Developing evidence for improving childhood vaccine adoption and uptake in low- and middle-income countries: a systematic review	2022	Aslam, F and Ali, I and Babar, ZUD and Yang, Y	EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Barriers to Human Papillomavirus Vaccination Among US Adolescents A Systematic Review of the Literature	2014	Holman, DM and Benard, V and Roland, KB and Watson, M and Liddon, N and Stokley, S	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
Acceptability of and barriers to human papillomavirus vaccination in China: A	2022	Wang, D and Wu, J and Du, JS and Ong, H and Tang, BW and Dozier, M and Weller, D and Campbell, C	RAYYAN-EXCLUSION-REASONS: focus on attitudes/perceptions	Wrong outcome

systematic review of the Chinese and English scientific literature				
Access to Vaccination among Disadvantaged, Isolated and Difficult-to-Reach Communities in the WHO European Region: A Systematic Review	2022	Ekezie, W and Awwad, S and Krauchenberg, A and Karara, N and Dembinski, L and Grossman, Z and del Torso, S and Dornbusch, HJ and Neves, A and Copley, S and Mazur, A and Hadjipanayis, A and Grechukha, Y and Nohynek, H and Damjanovic, K and Lazic, M and Papaevangelou, V and Lapii, F and Stein-Zamir, C and Rath, B and ImmuHubs Consortium	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
Canadian school-based HPV vaccine programs and policy considerations	2017	Shapiro, GK and Guichon, J and Kelaher, M	RAYYAN-EXCLUSION-REASONS: wrong outcome	Wrong outcome
A systematic review of factors affecting vaccine uptake in young children	2017	Smith, LE and Amlot, R and Weinman, J and Yiend, J and Rubin, GJ	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Parents' knowledge, beliefs, acceptance and uptake of the HPV vaccine in members of The Association of Southeast Asian Nations (ASEAN): A systematic review of quantitative and qualitative studies	2021	Wijayanti, KE and Schutze, H and MacPhail, C and Braunack-Mayer, A	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
Inequality in the distribution of Covid-19 vaccine: a systematic review.	2022	Bayati, Mohsen and Noroozi, Rayehe and Ghanbari-Jahromi, Mohadeseh and Jalali, Faride Sadat	RAYYAN-EXCLUSION-REASONS: does not report vaccine uptake	Wrong outcome
Factors Associated With Vaccination Compliance in Southeast Asian Children: A Systematic Review.	2021	Kalaij, Ayers Gilberth Ivano and Sugiyanto, Michael and Ilham, Ahmad Fadhil	RAYYAN-EXCLUSION-REASONS: does not report vaccine uptake	Wrong outcome
Disparities and reverse disparities in HPV vaccination: A systematic review and meta-analysis.	2019	Spencer, Jennifer C. and Calo, William A. and Brewer, Noel T.	RAYYAN-EXCLUSION-REASONS: does not report	Wrong outcome

			socioeconomic inequalities in vaccine uptake	
Factors affecting access to immunisation of under-five-year-olds.	2019	Wyllie-Schmidt, Cilla and Tipa, Zoã« and McClunie-Trust, Patricia	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
Hpv vaccine adherence among adolescents: integrative review.	2019	Calixto de Carvalho, Ayla Maria and Leite Rangel Andrade, Elaine Maria and Tolstenko Nogueira, Lãdya and Evangelista de Araãºjo, Telma Maria	RAYYAN-EXCLUSION-REASONS: does not report vaccine uptake	Wrong outcome
Vacunaciã³n contra Hepatitis B: un estudio de revisiã³n.	2017	de Araãºjo, Telma Maria Evangelista and de Sousa, Karinna Alves Amorim and Soares Dias, Samya Raquel and Cavalcante Oliveira, Vanessa and Bastos Marques, Evellyn Stefanne	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
Human Papillomavirus Vaccine Uptake, Knowledge, and Acceptance for Youth: A Systematic Review of Appalachia.	2018	Ryan, Chelsea and Duvall, Kathryn L. and Weyant, Emily C. and Johnson, Kiana R. and Wood, David	RAYYAN-EXCLUSION-REASONS: does not report socioeconomic inequalities in vaccine uptake	Wrong outcome
Postawy i edukacja wakcynologiczna rodzicã³w.	2018	DoÅ„ka, Katarzyna and SuwaÅ„a, Marlena and Zarzycka, Danuta and Sobolewska-Samorek, Agnieszka and PaÅºdzior, Violetta	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
HPV Vaccine Uptake Among Canadian Youth and The Role of the Nurse Practitioner.	2016	Scott, Katlyn and Batty, Mary	RAYYAN-EXCLUSION-REASONS: does not report the correct socioeconomic inequalities	Wrong outcome
The Impact of COVID-19 Pandemic on Inequity in Routine Childhood Vaccination Coverage: A Systematic Review	2022	Spencer, N., Markham, W., Johnson, S., Arpin, E., Nathawad, R., Gunnlaugsson, G., Homaira, N., Rubio, M.L.M., Trujillo, C.J.	RAYYAN-EXCLUSION-REASONS: wrong outcome	Wrong outcome

A scoping review of literature exploring factors affecting vaccine uptake within Roma communities across Europe	2022	Cronin, A., Ibrahim, N.	RAYYAN-EXCLUSION-REASONS: Mixed review: relevant information cannot be separated from the irrelevant	Wrong outcome
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Appendix 4.1 Diagram depicting the flow of COVER data (NHS Digital, 2023a).



Appendix 4.2 Table of vaccine administration quarters mapped to evaluation quarters.

Evaluation quarters				Time Points	Lag of 7 quarters		COVID-19 Events
A2016_Q1	2016-2017	April-June	0	A2014_Q2	2014-2015	July-September	
A2016_Q2	2016-2017	July-September	1	A2014_Q3	2014-2015	October-December	
A2016_Q3	2016-2017	October-December	2	A2015_Q4	2014-2015	January-March	
A2017_Q4	2016-2017	January-March	3	B2015_Q1	2015-2016	April-June	
B2017_Q1	2017-2018	April-June	4	B2015_Q2	2015-2016	July-September	
B2017_Q2	2017-2018	July-September	5	B2015_Q3	2015-2016	October-December	
B2017_Q3	2017-2018	October-December	6	B2016_Q4	2015-2016	January-March	
B2018_Q4	2017-2018	January-March	7	C2016_Q1	2016-2017	April-June	
C2018_Q1	2018-2019	April-June	8	C2016_Q2	2016-2017	July-September	
C2018_Q2	2018-2019	July-September	9	C2016_Q3	2016-2017	October-December	
C2018_Q3	2018-2019	October-December	10	C2017_Q4	2016-2017	January-March	
C2019_Q4	2018-2019	January-March	11	D2017_Q1	2017-2018	April-June	
D2019_Q1	2019-2020	April-June	12	D2017_Q2	2017-2018	July-September	
D2019_Q2	2019-2020	July-September	13	D2017_Q3	2017-2018	October-December	
D2019_Q3	2019-2020	October-December	14	D2018_Q4	2017-2018	January-March	
D2020_Q4	2019-2020	January-March	15	E2018_Q1	2018-2019	April-June	
E2020_Q1	2020-2021	April-June	16	E2018_Q2	2018-2019	July-September	
E2020_Q2	2020-2021	July-September	17	E2018_Q3	2018-2019	October-December	
E2020_Q3	2020-2021	October-December	18	E2019_Q4	2018-2019	January-March	
E2021_Q4	2020-2021	January-March	19	F2019_Q1	2019-2020	April-June	
F2021_Q1	2021-2022	April-June	20	F2019_Q2	2019-2020	July-September	
F2021_Q2	2021-2022	July-September	21	F2019_Q3	2019-2020	October-December	
F2021_Q3	2021-2022	October-December	22	F2020_Q4	2019-2020	January-March	Lockdown
F2022_Q4	2021-2022	January-March	23	G2020_Q1	2020-2021	April-June	Lagged lockdown
G2022_Q1	2022-2023	April-June	24	G2020_Q2	2020-2021	July-September	

G2022_Q2	2022-2023	July-September	25	G2020_Q3	2020-2021	October-December	Phase 1 COVID-19 vaccine rollout
G2022_Q3	2022-2023	October-December	26	G2021_Q4	2020-2021	January-March	Lagged Phase 1
G2023_Q4	2022-2023	January-March	27	H2021_Q1	2021-2022	April-June	Phase 2 COVID-19 vaccine rollout
H2023_Q1	2023-2024	April-June	28	H2021_Q2	2021-2022	July-September	
H2023_Q2	2023-2024	July-September	29	H2021_Q3	2021-2022	October-December	
H2023_Q3	2023-2024	October-December	30	H2022_Q4	2021-2022	January-March	
H2024_Q4	2023-2024	January-March	31	I2022_Q1	2022-2023	April-June	

Appendix 4.3 Table of COVER quarterly data caveats.

Date	Caveats
2016 Apr- Jun Q1	• Barnet - GP Data only - does not include unregistered population • Brent - GP Data only - does not include unregistered population • Ealing - GP Data only - does not include unregistered population • Enfield - GP Data only - does not include unregistered population • Hammersmith and Fulham - Data quality issues due to ongoing issues with CHIS IT supplier. Problems being addressed by provider and NHS England Local team. • Harrow - GP Data only - does not include unregistered population • Kensington and Chelsea - Data quality issues due to ongoing issues with CHIS IT supplier. Problems being addressed by provider and NHS England Local team. • Lincolnshire - GP Data only - does not include unregistered population • North Tyneside - Data quality issues with quarterly submission, being addressed by data provider and NHS England Local Team. • North Yorkshire - GP Data only - does not include unregistered population • Northumberland - Data quality issues with quarterly submission, being addressed by data provider and NHS England Local Team. • Tower Hamlets - GP Data only - does not include unregistered population - Data quality issues due to ongoing issues with CHIS IT supplier. Problems being addressed by provider and NHS England Local team. • Westminster - Data quality issues due to ongoing issues with CHIS IT supplier. Problems being addressed by provider and NHS England Local team. • York - GP Data only - does not include unregistered population.
2016 Jul- Sep Q2	• Barnet - GP Data only - does not include unregistered population • Blackburn with Darwen - Ongoing data quality issues with CHIS IT supplier being addressed by provider and NHS England Local team. • Brent - GP Data only - does not include unregistered population • Bromley - Data quality issues with MenB data being addressed by data provider and NHS England Local Team. • Ealing - GP Data only - does not include unregistered population • Enfield - GP Data only - does not include unregistered population • Haringey - GP Data only - does not include unregistered population • Harrow - GP Data only - does not include unregistered population • Hillingdon - Data quality issues being addressed by data provider and NHS England Local Team. • Isle of Wight - Data quality issues being addressed by data provider and NHS England Local Team. • Newham - GP Data only - does not include unregistered population • Norfolk - Data quality issues relating to last quarter's data have been resolved, resulting in an increase in the 12m, 24m and 5y denominators. • Northumberland - Data quality issues being addressed by data provider and NHS England Local Team. • Tower Hamlets - GP Data only - does not include unregistered population - Data quality issues with quarterly submission, being addressed by data provider and NHS England Local Team. • York - GP Data only - does not include unregistered population

2016 Oct-Dec Q3	• Barnet - GP Data only - does not include unregistered population • Bolton - Moved to a new Child Health Information System in November 2016, major cleansing exercise undertaken during transition • Bracknell Forest - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Brent - GP Data only - does not include unregistered population • Dudley - First data extraction following migration of Dudley/Walsall Child Health Information Systems into the Birmingham, Sandwell and Solihull systems. • Ealing - GP Data only - does not include unregistered population • Harrow - GP Data only - does not include unregistered population • North Yorkshire - GP Data only - does not include unregistered population • Reading - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Slough - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Tower Hamlets - GP Data only - does not include unregistered population • West Berkshire - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Walsall - First data extraction following migration of Dudley/Walsall Child Health Information Systems into the Birmingham, Sandwell and Solihull systems. • Windsor and Maidenhead - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Wokingham - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • York - GP Data only - does not include unregistered population
2016 Jan-Mar Q4	• Sussex - Community NHS Trust - Data quality issues with 5 year DTaP/IPV booster coverage ,which are being addressed by the NHS England local team and data provider. • Tower Hamlets PCT - GP Data only- does not include unregistered population • Westminster PCT - Data quality issued being addressed by NHS England local team and data provider. • 5yDTaP/IPV Booster % - The decrease in coverage of the pre-school booster (DTaP/IPV) for some English area teams is thought to be a data quality issue due to an inconsistency between the information provided by PHE in the COVER user guidance and the information standard and may have resulted in the data extraction of one of the main Child Health Information Systems (CHIS) under-estimating coverage of this booster. This is currently being investigated and the English coverage estimates for this vaccine should be interpreted with caution
2017	• Bedford - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17.

Apr- Jun Q1	• Bournemouth - A number of surgeries have recently migrated from one clinical system to another and this may have had an effect on the data extracted. • Bury - A new CHIS is being implemented and MenB data should be available from late 2017 • Cambridgeshire - A new provider has taken over the CHIS service from 1st April 2017 • Central Bedfordshire - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Cheshire East - Recently migrated from PARIS to EMIS Web. • City of London - City of London has been included in Hackney data. • Dorset - A number of surgeries have recently migrated from one clinical system to another and this may have had an effect on the data extracted. • LONDON REGION - There are now four CHIS Hubs providing COVER data the whole of London and the first data submitted from these newly established Hubs reflects a system in transition, therefore changes in LA vaccine coverage in London should be interpreted with caution. • Luton - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Milton Keynes - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Norfolk - A new provider has taken over the CHIS service from 1st April 2017 • North Yorkshire - GP Data only - does not include unregistered population • Oldham - A new CHIS is being implemented and MenB data should be available from late 2017 • Peterborough - A new provider has taken over the CHIS service from 1st April 2017 • Poole - A number of surgeries have recently migrated from one clinical system to another and this may have had an effect on the data extracted. • Rochdale - A new CHIS is being implemented and MenB data should be available from late 2017 • Suffolk - A new provider has taken over the CHIS service from 1st April 2017 • Surrey - The provider is still in the process of establishing a data warehouse to gather and report on data from all the CHIS systems. Therefore, they were unable to provide data for Qtr 1 2017-2018. • Trafford - A new CHIS is being implemented and MenB data should be available from late 2017 • York - GP Data only - does not include unregistered population
2017	

Jul-Sep Q2	• Bedford - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Blackburn with Darwen - Following transition to a new CHIS system in August 2017 this is the first quarter Men B has been submitted. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B vaccinations appropriately. There is low confidence in the robustness of the data for Rotavirus immunisation uptake due to an historic inability of the old system to schedule and record Rotavirus vaccinations appropriately. Data quality concerns are particularly notable in Blackburn with Darwen • Blackpool - Following transition to a new CHIS system in August 2017 this is the first quarter Men B has been submitted. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B vaccinations appropriately. There is low confidence in the robustness of the data for Rotavirus immunisation uptake due to an historic inability of the old system to schedule and record Rotavirus vaccinations appropriately. • Bournemouth - A number of surgeries have recently migrated from one clinical system to another and this may have had an effect on the data extracted. • Bury - A new CHIS has recently been implemented. • Cambridgeshire - rovide have taken over the CHIS service on 1st April 2017. • Central Bedfordshire - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Cheshire East - Recently migrated from ARIS to EMIS Web. • City of London - City of London has been included in Hackney data. • Dorset - A number of surgeries have recently migrated from one clinical system to another and this may have had an effect on the data extracted. • Hampshire - The decrease in Rotavirus coverage is being investigated locally. • Lancashire - There is low confidence in the robustness of the data for all immunisations across Lancashire local authority due to data quality concerns in one CCG area which is adversely affecting overall uptake. The caveats relating to MenB and Rotavirus outlined for Blackburn with Darwen and Blackpool (see above) also apply. • LONDON REGION - There are now four CHIS Hubs providing COVER data the whole of London and the data submitted from these newly established Hubs reflects a system in transition, therefore changes in LA vaccine coverage in London should be interpreted with caution. • Luton - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Milton Keynes - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Norfolk - rovide have taken over the CHIS service on 1st April 2017. • North Yorkshire - GP Data only - does not include unregistered population • Oldham - A new CHIS has recently been implemented. • eterborough - rovide have taken over the CHIS service on 1st April 2017. • oole - A number of surgeries have recently migrated from one clinical system to another and this may have had an effect on the data extracted. • Rochdale - A new CHIS has recently been implemented. • Southampton - Data unavailable from one practice • Suffolk - rovide have taken over the CHIS service on 1st April 2017.
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	• Surrey - The provider has recently established a data warehouse to gather and report on data from all the CHIS systems. • Trafford - A new CHIS has recently been implemented. • York - GP Data only - does not include unregistered population - 5 year cohort data incomplete for one practice due to possible incorrect readcode during data transfer.
2017 Oct- Dec Q3	• Bedford - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health. • Blackburn with Darwen - Following transition to a new CHIS system in August 2017, this is only the second quarter they have been able to submit data for Men B uptake. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B vaccinations appropriately. There is low confidence in the robustness of the data for Rotavirus immunisation uptake due to an historic inability of the old system to schedule and record Rotavirus vaccinations appropriately (particularly notable in Blackburn with Darwen). • Blackpool - Following transition to a new CHIS system in August 2017, this is only the second quarter they have been able to submit data for Men B uptake. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B vaccinations appropriately. There is low confidence in the robustness of the data for Rotavirus immunisation uptake due to an historic inability of the old system to schedule and record Rotavirus vaccinations appropriately. • Bury - A new CHIS has recently been implemented. • Cambridgeshire - Ongoing data quality issues within rovide including information from NHS Digital Registration. • Central Bedfordshire - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health. • Cumbria - First quarter of data since moving from CCH2000 (HSW) to RiO system • City of London - City of London has been included in Hackney data. • Knowsley - Services migrated to RIO on 1st December 2017 • Lancashire - There is low confidence in the robustness of the data for all immunisations across Lancashire local authority due to data quality concerns in one CCG area which is adversely affecting overall uptake. Following transition to a new CHIS system in August 2017, this is only the second quarter they have been able to submit data for Men B uptake. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B vaccinations appropriately. There is low confidence in the robustness of the data for Rotavirus immunisation uptake due to an historic inability of the old system to schedule and record Rotavirus vaccinations appropriately.

	• LONDON REGION - There are now four CHIS Hubs providing COVER data the whole of London and the data submitted from these newly established Hubs reflects a system in transition, therefore changes in LA vaccine coverage in London should be interpreted with caution. • Luton - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health. • Milton Keynes - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health. • Norfolk - Ongoing data quality issues within rovide including information from NHS Digital Registration. • North Yorkshire - GP Data only - does not include unregistered population • Oldham - A new CHIS has recently been implemented. • eterborough - Ongoing data quality issues within rovide including information from NHS Digital Registration. • Rochdale - A new CHIS has recently been implemented. • Southampton - Data unavailable from one practice • Suffolk - Ongoing data quality issues within rovide including information from NHS Digital Registration. • Surrey - The provider has recently established a data warehouse to gather and report on data from all the CHIS systems. • Trafford - A new CHIS has recently been implemented. • York - GP Data only - does not include unregistered population
2017 Jan- Mar Q4	• Barnet - GP Data only - does not include unregistered population • Bedford - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Bolton - Moved to a new Child Health Information System in November 2016, major cleansing exercise undertaken during transition • Bracknell Forest - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Brent - GP Data only - does not include unregistered population • Bury - A new CHIS is being implemented and MenB data should be available from late 2017 • Central Bedfordshire - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Dudley - Second data extraction following migration of Dudley/Walsall Child Health Information Systems into the West Midland CHIS.

	• Ealing - GP Data only - does not include unregistered population • Harrow - GP Data only - does not include unregistered population • LONDON REGION - COVER Q4 2016/17 data was collected during a time of transition from 19 CHIS providers to 4 CHIS Hubs in London. This has complicated data collection process in some areas of London • Luton - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Milton Keynes - Hertfordshire Community Trust was commissioned for Central Midlands South Child Health from the 1st April 17. • Newham - GP Data only - does not include unregistered population • North Tyneside - Staff on long term sick leave and general staff shortages meant some of the routine data cleansing and chasing of immunisations did not take place. • North Yorkshire - No immunisation data received from one GP practice. previously the data was gathered directly from GPs and now the data is gathered from the Child Health system (using data from GPs). • Oldham - A new CHIS is being implemented and MenB data should be available from late 2017 • Reading - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Redcar and Cleveland - GP practices have closed down on the borders of Redcar and the decrease in denominators could result from patients moving to GPs in other areas. • Rochdale - A new CHIS is being implemented and MenB data should be available from late 2017 • Slough - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Tower Hamlets - GP Data only - does not include unregistered population • Trafford - A new CHIS is being implemented and MenB data should be available from late 2017 • Walsall - Following the migration of Walsall data on to the West Midlands CHIS, the reported uptake for Q4 2016/17 continues to be investigated. • West Berkshire - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Windsor and Maidenhead - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission. • Wokingham - SCW CSU assumed responsibility for Berkshire Child Health from 1st January 2017 and changes have been introduced in operational and reporting processes to improve data quality which will have affected the COVER submission.
2018 Apr- Jun Q1	• Bath and North East Somerset - "4 GP practices did not respond to requests for COVER data despite two requests via email" • Bedford - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats.

- Blackburn with Darwen - Some children with unknown GP who are resident within locality were not included in previous submissions
- Blackpool - Some children with unknown GP who are resident within locality were not included in previous submissions
- Bolton - Three GP practices in the Bolton area have over 100 children waiting for vaccinations.
- Bury - Due to changes in IT systems they currently have a back log of immunisation data to be entered, so figures will appear lower than normal.
- Cambridgeshire - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Central Bedfordshire - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats.
- City of London - City of London has been included in Hackney data.
- England - The migration of GP data to the NE London CHIS hub has affected coverage estimates for many of the LAs reported by this hub. As a consequence, London-level coverage figures are under-estimated this quarter. Due to the impact London data has on national figures, England estimates have not been calculated for this report.
- Essex - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Gloucestershire - 31 GP practices did not respond to requests for COVER data despite two requests via email
- Hertfordshire - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats.
- Lancashire - There remains low confidence in the data return for one CCG area within the Lancashire County Council footprint, which is adversely affecting uptake across the area. Early investigation of the data by direct comparison indicates higher levels than reported. This is under urgent investigation and a deep dive is underway to validate these early findings.
- LONDON REGION - There are now four CHIS Hubs providing COVER data the whole of London and the data submitted from these newly established Hubs reflects a system in transition, therefore changes in LA vaccine coverage in London should be interpreted with caution. articular data quality issues have been identified in the North East hub for this quarter.
- Luton - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats.
- Milton Keynes - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats.
- Norfolk - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- eterborough - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Southend-on-Sea - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Suffolk - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Swindon - 8 GP practices did not respond to requests for COVER data despite three requests via email.

	Thurrock - Ongoing data quality issues within rovide including information from NHS Digital Registration.
2018 Jul-Sep Q2	- Bath and North East Somerset - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. A small number of practices are experiencing issues providing electronic immunisation data for uploading. This is being addressed and should be reflected more positively in the annual data. - Bedford - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. - Bracknell Forest - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. - Buckinghamshire - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. - Cambridgeshire - Ongoing data quality within rovide including information from NHS Digital Registration. - Central Bedfordshire - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. - Cheshire West and Chester - Data unavailable for Neston. - City of London - City of London has been included in Hackney data. - Essex - Ongoing data quality within rovide including information from NHS Digital Registration. - Gateshead- The system has changed from CCH2000 to EMIS and a large amount of data cleansing has taken place. - Gloucestershire - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be

	reflected more positively in the annual data. A small number of practices are experiencing issues providing electronic immunisation data for uploading. This is being addressed and should be reflected more positively in the annual data. • Hertfordshire - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Kent - An extensive data cleansing exercise was carried out for the Q2 submission. • Lancashire- There is low confidence in the data for one CCG within Lancashire, which is adversely affecting uptake across the area. Although data is improving, actions are on-going to provide resolution. • LONDON REGION- Since April 2017, four CHIS Hubs provide COVER data for the whole of London and the data submitted from these newly established Hubs reflects a system in transition. The NE London Hub reported data quality issues associated with a second phase of migrating data in July 2018 which resulted in decreases in London-level coverage estimates at 12 and 24 month and 5 year evaluations. Due to the impact London data has on national figures there were no national or UK level data published in the previous quarter. Although data quality has improved, in particular for legacy data, these issues are have not been completely resolved and July to September 2018 quarter (Q2) data for London continues to be affected by complexities in data flows between providers and child health information systems, and inconsistencies in data coding. • Luton - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Medway - An extensive data cleansing exercise was carried out for the Q2 submission. • Milton Keynes - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Norfolk - Ongoing data quality within rovide including information from NHS Digital Registration. • Oldham - They are now reporting based on the responsible CCG of the child rather than the borough they were treated in. • Oxfordshire - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. Oxfordshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. • eterborough - Ongoing data quality within rovide including information from NHS Digital Registration. • Reading - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. • Rochdale - They are now reporting based on the responsible CCG of the child rather than the borough they were treated in.
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- Shropshire- Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Slough - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data.
- Southend-on-Sea - Ongoing data quality within rovide including information from NHS Digital Registration.
- Staffordshire - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Stoke-on-Trent - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Suffolk - Ongoing data quality within rovide including information from NHS Digital Registration.
- Swindon - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. A small number of practices are experiencing issues providing electronic immunisation data for uploading. This is being addressed and should be reflected more positively in the annual data.
- Telford and Wrekin - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Thurrock - Ongoing data quality within rovide including information from NHS Digital Registration.
- Walsall - Several thousand new registrations have been completed on Careplus from the NHS digital validation report.
- West Berkshire - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data.
- Windsor and Maidenhead- There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and

	should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. • Wokingham - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. • Wolverhampton - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
2018 Oct-Dec Q3	• Bath and North East Somerset - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. A small number of practices are experiencing issues providing electronic immunisation data for uploading. This is being addressed and should be reflected more positively in the annual data. • Barnet - 1 GP practice did not share data with CHIS. Increase in Year 5 denominator after movers in/out upload. • Bedford - A new report processing methodology for COVER statistics has been implemented for this financial year. A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Bexley - Out of 24 practices we have not received data since June for one practice, October for another and a further practice is missing December. • Bournemouth - A larger than normal variance was noted between Q2 and Q3 for the Bournemouth 12 month cohort as a consequence of the NHS D -CHIS validation exercise that commenced during Q2 2018-19 • Bracknell Forest - The issues with the automated upload of MenB data highlighted in the Q2 caveat has now been resolved. There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. • Bromley - Out of 45 practices we have not received data since September for two practices, October for a further one and one more is missing December's data • Buckinghamshire - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation

	records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. • Bury - Reported to be behind in entering the Immunisation data on to the Child Health System. This is currently being worked on. • Central Bedfordshire - A new report processing methodology for COVER statistics has been implemented for this financial year. A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Cheshire West and Chester - Data unavailable for Neston. • City of London - City of London has been included in Hackney data. City of London has been included in Hackney data. • Gateshead - The system has changed from CCH2000 to EMIS and a large amount of data cleansing has taken place. • Gloucestershire - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. A small number of practices are experiencing issues providing electronic immunisation data for uploading. This is being addressed and should be reflected more positively in the annual data. • Greenwich - One of 35 practices is missing data for December. • Havering - 6 GPs have not shared data with CHIS for this quarter - no electronic transfer of data • Hertfordshire - A new report processing methodology for COVER statistics has been implemented for this financial year. A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Islington - 2 GPs have not shared data with CHIS for this quarter • Kent - An extensive data cleansing exercise was carried out for the Q2 submission. • Lambeth - Out of 42 practices we have not received data since October for one practice and December for a further three. • Lancashire- There is low confidence in the data for one CCG within Lancashire, which is adversely affecting uptake across the area. Although data is improving, actions are on-going to provide resolution. • LONDON REGION - "Since April 2017, four CHIS Hubs provide COVER data for the whole of London and the data submitted from these newly established Hubs reflects a system in transition. Issues relating to complexities in data flows between providers and child health information systems (CHISs), and inconsistencies in data coding resulted in decreases in London-level coverage estimates for the 12 and 24 month and 5 year evaluations being first reported six months ago. Due to the impact London data has on national figures no national or UK level data were published in the April to June 2018 quarter. • To assess trends in coverage accounting for the data quality issues, England (all) were published alongside England (excluding London) figures for the previous and current quarters. However, data quality improved for the July to September 2018 quarter, in particular for legacy data, and unless there are further concerns the next report will not include England data excluding London • "Since April 2017, four CHIS Hubs provide COVER data for the whole of London and the data submitted from these newly established Hubs reflects a system in transition. The
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NE London Hub reported data quality issues associated with a second phase of migrating data in July 2018 which resulted in decreases in London-level coverage estimates at 12 and 24 month and 5 year evaluations. Due to the impact London data has on national figures there were no national or UK level data published in the previous quarter. Although data quality has improved, in particular for legacy data, these issues are have not been completely resolved and July to September 2018 quarter (Q2) data for London continues to be affected by complexities in data flows between providers and child health information systems, and inconsistencies in data coding.

- Luton - A new report processing methodology for COVER statistics has been implemented for this financial year. A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats.
- Manchester - Reported reason for the drop in uptake is due to the NHS Digital valisation exercise; thousands of records were received between October and December and in this period moved large numbers of children onto the system. Where possible the team tried to obtain immunisation histories, but large numbers were movements in with no history on spine to chase.
- Medway - An extensive data cleansing exercise was carried out for the Q2 submission.
- Milton Keynes - A new report processing methodology for COVER statistics has been implemented for this financial year. - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats.
- Oldham - A number of practices have long queue lists. SIT aware of this. The system prioritises the youngest first. - They are now reporting based on the responsible CCG of the child rather than the borough they were treated in.
- Oxfordshire - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. Oxfordshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data.
- Reading - The issues with the automated upload of MenB data highlighted in the Q2 caveat has now been resolved. - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data.
- Redbridge - Some GPs have not shared data with CHIS - no electronic transfer of data available.
- Rochdale - Moved from CH to aris CH with a more robust inputting. Now using Tableau instead of Report Manager. Have streamlined the current reporting suite to run via GP Team and the ennine Status is more accurate. They are now reporting based on the responsible CCG of the child rather than the borough they were treated in.

- Shropshire - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Slough - The issues with the automated upload of MenB data highlighted in the Q2 caveat has now been resolved. There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data.
- Staffordshire - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Stoke-on-Trent - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Swindon - There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. A small number of practices are experiencing issues providing electronic immunisation data for uploading. This is being addressed and should be reflected more positively in the annual data.
- Tameside - In December CHIS Validation work was commenced which meant that children were moved into the area without an immunisation status until the child had been seen by the GP. The process for calling for immunisations for children that DNA has been reviewed, these are now added back into the schedule automatically as well as sending the lists of children that are out of circulation to GP practices to advise that they have DNA'd a number of times. The previous process was to await instruction from the GP practice of whether to reinstate the children.
- Telford and Wrekin - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
- Walsall - Several thousand new registrations have been completed on Careplus from the NHS digital validation report.
- West Berkshire - The issues with the automated upload of MenB data highlighted in the Q2 caveat has now been resolved. There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data.

	- Windsor and Maidenhead - The issues with the automated upload of MenB data highlighted in the Q2 caveat has now been resolved. There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. - Wokingham - The issues with the automated upload of MenB data highlighted in the Q2 caveat has now been resolved. There are increased cohorts across the patch due to the NHS data validation exercise. Many of these children will not have up to date immunisation records and we hope that once immunisation histories have been received they will be reflected more positively in the annual data. There is a known issue with the electronic upload of MenB in Berkshire. This is being addressed and should be reflected more positively in the annual data. Berkshire are experiencing a change in process for receiving immunisation data to an electronic process which has raised some data quality issues. This is being addressed and should be reflected more positively in the annual data. - Wolverhampton - Denominator may show an increase from previous reporting results due to CHIS working through the 0-5 year old Personal Demographic Service (DS) report provided from NHS Digital (NHSD), which is highlighting Movements In to area.
2018 Jan-Mar Q4	- Bedford - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health. - Blackburn with Darwen - Following transition to a new CHIS system in August 2017, this is only the third quarter Blackburn with Darwen has been able to submit data for Men B and Rotavirus uptake. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B and Rotavirus vaccinations appropriately. Currently Lancashire DCO is unable to report on Hep B vaccine coverage for at risk infants. There are data quality issues with the comparison between ImmForm extractions and CHIS data that informs COVER. - Blackpool - Following transition to a new CHIS system in August 2017, this is only the third quarter Blackpool has been able to submit data for Men B and Rotavirus uptake. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B and Rotavirus vaccinations appropriately. Currently Lancashire DCO is unable to report on Hep B vaccine coverage for at risk infants. There are data quality issues with the comparison between ImmForm extractions and CHIS data that informs COVER. - Bournemouth - population denominator fluctuations, particularly in the Poole area, may be due incorrect mapping within the ODS download which has changed the overarching LA from one to another within Dorset, also some practices have closed or merged during the reporting period which may also have contributed to the fluctuations. - Bury - Supplier: CCH2000 from 01/01/2018- 16/03/2018. From 16/03/18 - 26/03/18 inputting was halted due to migration onto aris. - Cambridgeshire - Ongoing data quality issues within provide including information from NHS Digital Registration.

- Central Bedfordshire - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health.
- Cumbria - Second quarter of data since moving from CCH2000 (HSW) to RiO system
- City of London - City of London has been included in Hackney data.
- Dorset - opulation denominator fluctuations, particularly in the oole area, may be due incorrect mapping within the ODS download which has changed the overarching LA from one to another within Dorset, also some practices have closed or merged during the reporting period which may also have contributed to the fluctuations.
- Essex - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Hertfordshire - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health.
- Knowsley - Services migrated to RIO on 1st December 2017
- Lancashire - Following transition to a new CHIS system in August 2017, this is only the third quarter Lancashire has been able to submit data for Men B and Rotavirus uptake. There is low confidence in the robustness of this data due to an historic inability of the old system to schedule and record Men B and Rotavirus vaccinations appropriately. Currently Lancashire DCO is unable to report on Hep B vaccine coverage for at risk infants. There are data quality issues with the comparison between ImmForm extractions and CHIS data that informs COVER. There is low confidence in the robustness of the data for all immunisations across Lancashire local authority due to data quality concerns in one CCG area that is adversely affecting overall uptake.
- LONDON REGION - There are now four CHIS Hubs providing COVER data the whole of London and the data submitted from these newly established Hubs reflects a system in transition, therefore changes in LA vaccine coverage in London should be interpreted with caution.
- Luton - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health.
- Milton Keynes - From the 1st April 17, Hertfordshire Community Trust is commissioned for Central Midlands South Child Health.
- Norfolk - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Northumberland - Some system issues exist and we cannot at present be assured that the data is a true representation of vaccination activity.
- Oldham - Supplier: Health Solutions Wales from 01/01/2018- 16/03/2018. From 16/03/18 - 26/03/18 inputting was halted due to mirgration onto aris
- eterborough - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- oole - opulation denominator fluctuations, particularly in the oole area, may be due incorrect mapping within the ODS download which has changed the overarching LA from one to another within Dorset, also some practices have closed or merged during the reporting period which may also have contributed to the fluctuations.
- Rochdale - Supplier: Health Solutions Wales from 01/01/2018- 16/03/2018. From 16/03/18 - 26/03/18 inputting was halted due to mirgration onto aris.
- Southend-on-Sea - Ongoing data quality issues within rovide including information from NHS Digital Registration.
- Suffolk - Ongoing data quality issues within rovide including information from NHS Digital Registration.

	• Sunderland - The reduction in coverage at 12 months may not be correct and is being investigated locally. • Surrey - The provider has recently established a data warehouse to gather and report on data from all the CHIS systems. • Thurrock - Ongoing data quality issues within rovide including information from NHS Digital Registration. • Trafford - Supplier: Health Solutions Wales from 01/01/2018- 16/03/2018. From 16/03/18 - 26/03/18 inputting was halted due to mirgration onto aris.
2019 Apr- Jun Q1	• Barking and Dagenham - There are 19 GPs across Barking, Havering and Redbridge who have not shared data in the recent upload. • Bexley - Data missing for all of Qtr 1 from 1 ractice and for June from 3 ractices. • Bromley - Data missing for all of Qtr 1 from 1 ractice and for June from 2 ractices. • Bury - Supressed due to Data Quality Issues • City of London - City of London has been included in Hackney data. • Enfield - 5 GP ractices have not shared their data this quarter. • Havering - There are 19 GPs across Barking, Havering and Redbridge who have not shared data in the recent upload. • Haringey - 1 GP ractice has not shared their data this quarter. • Lambeth - Data missing for May & June from 2 ractices and for June from 1 ractice. • Newham - 2 GP ractices have not shared their data this quarter. • North Yorkshire - Figures include data from 2 military GP practices (A91037 & A91024). Data is incomplete - unable to gather vaccinations data from Defence Medical Information Capability rogramme (DMICP) at this time. • Redbridge - There are 19 GPs across Barking, Havering and Redbridge who have not shared data in the recent upload. • Southwark - Data missing for June from 2 ractices. • Waltham Forest - Data Validation issues with DDS (Data Linkage)
2019 Jul- Sep Q2	• Barking and Dagenham - Work continues with data linkage company to extract all imms codes. • Bexley - Data for this quarter was not provided by 1 practice, and no data was provided for August and September by 2 practices. • Bromley - Data for this quarter was not provided by 1 practice, and no data was provided for August and September by 3 practices, and no data was provided for September alone by 2 practices. • Bury - The Greater Manchester Screening and Immunisation Team and Bury CHIS are working collaboratively to improve data quality. This is an ongoing process and may manifest in spikes of uptake in quarterly figures. • City of London - City of London has been included in Hackney data. • Greenwich - Data for August and September was not provided by 1 practice, and no data was provided for September alone by 4 practices. • Havering - Work continues with data linkage company to extract all imms codes • Isle of Wight - Data validation targeting the 5-years cohort has resulted in a more accurate estimate of coverage. IOW has begun scheduling vaccinations in August which will impact data captured in the future. • Lambeth - Data for this quarter was not provided by 1 practice, and no data was provided for August and September by 1 practice, and no data was provided for September alone by 2 practices.

	• Lewisham - Data for September was not provided by 1 practice. • Oldham - The Greater Manchester Screening and Immunisation Team and Oldham CHIS are working collaboratively to improve data quality. This is an ongoing process and may manifest in spikes of uptake in quarterly figures. • Redbridge - Work continues with data linkage company to extract all imms codes. • Rochdale - The Greater Manchester Screening and Immunisation Team and Rochdale CHIS are working collaboratively to improve data quality. This is an ongoing process and may manifest in spikes of uptake in quarterly figures. • Southwark - Data for August and September was not provided by 1 practice, and no data was provided for September alone by 2 practices. • Thurrock - A GP practice previously not providing data has now begun to do so, resulting in an increase in numbers. • Trafford - The Greater Manchester Screening and Immunisation Team and Trafford CHIS are working collaboratively to improve data quality. This is an ongoing process and may manifest in spikes of uptake in quarterly figures.
2019 Oct-Dec Q3	• Bexley - "Data for December not provided by 2 practices. • Improved data flows of BCG vaccination information from community and maternity units to GP systems, has led to a large increase in coverage reported. " • Bromley - "Data for December not provided by 1 practice. • Improved data flows of BCG vaccination information from community and maternity units to GP systems, has led to a large increase in coverage reported. " • Bury - Due to data quality concerns for Bury, Oldham, Rochdale and Trafford LA COVER data for these footprints do not appear in this report. They are also excluded from any higher aggregations such as the North (Lancashire and Greater Manchester), North West (GOR), England and UK totals. • Camden - Data for this quarter was not provided by 1 practice. • City of London - City of London has been included in Hackney data. • Croydon - Improved data flows of BCG vaccination information from maternity units to GP systems, has led to a large increase in coverage reported. • Greenwich - Data for December not provided by 1 practice. • Hampshire - Data validation processes are in place to increase accuracy of the 5 year cohort. • Kingston Upon Thames - Increased data transfers from school vaccination records to the CHIS hubs has increased the number of children included in the 5 years cohort. • Lambeth - "Data for December alone not provided by 2 practices, whilst data for December and November not provided by 1 practice. • Improved data flows of BCG vaccination information from community and maternity units to GP systems, has led to a large increase in coverage reported. " • Merton - Improved data flows of BCG vaccination information from maternity units to GP systems, has led to a large increase in coverage reported. • Newham - Data for this quarter was not provided by 2 practices. • Oldham - Due to data quality concerns for Bury, Oldham, Rochdale and Trafford LA COVER data for these footprints do not appear in this report. They are also excluded from any higher aggregations such as the North (Lancashire and Greater Manchester), North West (GOR), England and UK totals. • Portsmouth - Ongoing data validation of eligible children has resulted in more accurate denominators.

	• Rochdale - Due to data quality concerns for Bury, Oldham, Rochdale and Trafford LA COVER data for these footprints do not appear in this report. They are also excluded from any higher aggregations such as the North (Lancashire and Greater Manchester), North West (GOR), England and UK totals. • Southwark - "Data for December not provided by 1 practice. • Improved data flows of BCG vaccination information from community and maternity units to GP systems, has led to a large increase in coverage reported. " • Surrey - The provider has recently moved over to a new IT system • Sutton - Improved data flows of BCG vaccination information from maternity units to GP systems, has led to a large increase in coverage reported. • Trafford - Due to data quality concerns for Bury, Oldham, Rochdale and Trafford LA COVER data for these footprints do not appear in this report. They are also excluded from any higher aggregations such as the North (Lancashire and Greater Manchester), North West (GOR), England and UK totals. • Wandsworth - Improved data flows of BCG vaccination information from maternity units to GP systems, has led to a large increase in coverage reported.
2019 Jan-Mar Q4	• Barking and Dagenham - 4 GP practices have not shared data. • Barnet - 1 GP practice did not share data with the CHIS this quarter. • Bedford - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Bexley - Out of 24 practices we have not received data since June for one practice and December for another. March's data is outstanding for a further 2 practices. • Bolton - A significant number of immunisation sessions were cancelled in Bolton between Jan-March. Additional levels of validation have identified data that should not be included; there will be a difference for next submission. The NHS Digital validation report has identified children that should be removed from the dataset. • Bournemouth - Due to the MIMO validation exercise the data submitted may show anomalies as compared to previous quarters. • Bromley - Out of 44 practices we have not received data since September for one practice. March data is outstanding for one further practice. • Bury - previous back log of immunisations needed to be entered. Data cleansing is being conducted which has had a positive impact on the figures. • Camden - 3 GP practices have not shared data with the CHIS this quarter. • Central Bedfordshire - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • City of London - City of London has been included in Hackney data. • Dorset - Due to the MIMO validation exercise the data submitted may show anomalies as compared to previous quarters. • Havering - 2 GPs have not shared data with the CHIS this quarter. • Hertfordshire - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Lambeth - Out of 42 practices we have not received data since January for three practices. March data is outstanding for a further practice. • Lewisham - Out of 36 practices, March data is outstanding for one practice. • LONDON REGION - Since April 2017, four CHIS Hubs provide COVER data for the whole of London and the data submitted from these newly established Hubs reflects a system in transition. Issues relating to complexities in data flows between providers and child

	health information systems (CHISs), and inconsistencies in data coding, resulted in decreases in London-level coverage estimates for the 12 and 24 month and 5 year evaluations being first reported six months ago. However, London data quality has improved from the July to September 2018, in particular for legacy data, and no further concerns have arisen. • Luton - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Milton Keynes - A new report processing methodology has been implemented for this financial year which allows for a truer and more accurate picture of COVER stats. • Newham - 2 GP practices have not shared data with the CHIS this quarter. • Poole - Due to the MIMO validation exercise the data submitted may show anomalies as compared to previous quarters. • Portsmouth - We have a number of children we have recently moved in from abroad (a number from the HSCIC checking report) and we had either no imms or an incomplete immunisation history. • Redbridge - 22 GP practices have not shared data with the CHIS this quarter. • Southampton - We have a number of children who have recently moved in from abroad (a number from the HSCIC checking report) and we had either no imms or an incomplete immunisation history. • Southwark - Out of 36 practices we have not received data since December for one practice and January for another. • Stockport - Additional levels of validation have identified data that should not be included; there will be a difference for next submission. The NHS Digital validation report has identified children that should be removed from the dataset. • Surrey - Data fluctuations are due to the ongoing data revalidation work. • Tameside - Additional levels of validation have identified data that should not be included; there will be a difference for next submission. The NHS Digital validation report has identified children that should be removed from the dataset. • Waltham Forest - 2 GP practices have not shared data with the CHIS this quarter.
2020 Apr- Jun Q1	• Bath and North East Somerset - Increased vaccine coverage has been attributed to targeted work to obtain immunisation data from GP practices. • Bexley - 1 GP practice has not submitted data for this quarter. • Bromley - "2 GP practices have not submitted data for June. • 1 GP practice has not submitted data for May or June." • Camden - "Increases in BCG counts has been attributed to improved transfer of data onto the CHIS system. • Two GP practices have not submitted data this quarter." • City of London - City of London has been included in Hackney data. • Cornwall - 1 GP practice has not submitted 12 month cohort data for this quarter. • Greenwich - 1 GP practice has not submitted data this quarter. • Islington - Increases in BCG counts has been attributed to improved transfer of data onto the CHIS system. • Lambeth - "1 GP practice has not exported data for this quarter. • 1 GP practice has not exported data for May and June. • 2 GP practices have not exported for June only." • Liverpool - A change in CHIS services provider and system in this area, and resulting data cleansing, has been attributed to some changes seen in coverage.

	• Newham - Increases in BCG coverage has been attributed to to improved transfer of data onto the CHIS system. • North Yorkshire - 2 military GPs not included. • Southwark - "2 GP practices have not submitted data for this Quarter. • 3 GP practices have not submitted data for May or June." • Surrey - Denominators for 2019/20 Quarter 3 and 4 were underreported - Q1 has returned to previous higher levels. Coverage has remained stable throughout all the quarters.
2020 Jul-Sep Q2	• Bexley - "2 GP practices have not submitted data for September. • 1 GP practice has not exported data for August and September. • Birmingham - "CHIS and West Midlands HE recognise the Q2 submission shows significant reductions in cover rates across a number of areas. CHIS has reviewed the submitted cover data and has confirmed it accurately reflects the data recorded in the CHIS system. • CHIS and West Midlands HE are investigating the practice level data in detail to ascertain what if any underlying factors have contributed to the reduced cover and will identify and implement any actions arising from this investigation." • Bromley"2 GP practices have not submitted data for September. • 1 GP practice has not exported data for August and September." • City of LondonCity of London has been included in Hackney data. • Dudley "CHIS and West Midlands HE recognise the Q2 submission shows significant reductions in cover rates across a number of areas. CHIS has reviewed the submitted cover data and has confirmed it accurately reflects the data recorded in the CHIS system. • CHIS and West Midlands HE are investigating the practice level data in detail to ascertain what if any underlying factors have contributed to the reduced cover and will identify and implement any actions arising from this investigation." • Greenwich"2 GP practices have not submitted data for September. • 1 GP practice has not exported data for August and September. • 1 GP practice has not exported data for the whole of Quarter 2. • Lambeth"3 GP practices have not exported data for September. • 1 GP practice has not exported data since May. • Lewisham - 1 GP practice has not exported data for the whole of Quarter 2. • North Yorkshire - 2 military GP practices not included. • Nottingham - 12 month data has not been included due to data quality issues which are being investigated locally • lymouth - 1 GP practice has not submitted data due to an issue with the Data Sharing Agreement (DSA). • Sandwell - "CHIS and West Midlands HE recognise the Q2 submission shows significant reductions in cover rates across a number of areas. CHIS has reviewed the submitted cover data and has confirmed it accurately reflects the data recorded in the CHIS system. • CHIS and West Midlands HE are investigating the practice level data in detail to ascertain what if any underlying factors have contributed to the reduced cover and will identify and implement any actions arising from this investigation. • Solihull - "CHIS and West Midlands HE recognise the Q2 submission shows significant reductions in cover rates across a number of areas. CHIS has reviewed the submitted

	cover data and has confirmed it accurately reflects the data recorded in the CHIS system. • CHIS and West Midlands HE are investigating the practice level data in detail to ascertain what if any underlying factors have contributed to the reduced cover and will identify and implement any actions arising from this investigation. • Southwark - "2 GP practices have not submitted data for September. • 1 GP practice has not exported data for August and September. • St Helens - There has been a change in CHIS service provider and data has been migrated into a new system. • Trafford - A increase in the 5 year denominator has been attributed to improved data on eligible children. • Walsall - "CHIS and West Midlands HE recognise the Q2 submission shows significant reductions in cover rates across a number of areas. CHIS has reviewed the submitted cover data and has confirmed it accurately reflects the data recorded in the CHIS system. • CHIS and West Midlands HE are investigating the practice level data in detail to ascertain what if any underlying factors have contributed to the reduced cover and will identify and implement any actions arising from this investigation." • Warrington - "There has been a change in CHIS service provider and data has been migrated into a new system.
2020 Oct-Dec Q3	• Bexley - "1 GP practice has not exported data for December. • 1 GP practice has not exported data for November and December." • Bromley - 3 GP practices have not exported data for December. • Bury - The CHIS migrated to both a new system and information team in December. • City of London - City of London has been included in Hackney data. • Greenwich - "4 GP practices have not exported data for December. • 1 GP practice has not exported data for November and December." • Lambeth - "1 GP practice has not exported data for December. • 1 GP practice has not exported data for November and December • 2 GP practices have not exported data for the whole of Quarter 3 " • Lewisham - 1 GP practice has not exported data for the whole of Quarter 3. • North Yorkshire - 2 military GP practices not included. • Oldham - The CHIS migrated to both a new system and information team in December. • Rochdale - The CHIS migrated to both a new system and information team in December. • Southwark - 1 GP practice has not exported data for November and December • Trafford - The CHIS migrated to both a new system and information team in December. • Tameside - In previous quarters, some practices were incorrectly attached to the Tameside ODS Local Authority code. This issue has been corrected and the fall in denominators reflect this change.
2020 Jan-Mar Q4	• Bexley - At the time of submission 7 Bexley practices were yet to refresh their outstanding data for February and March. • Blackpool - Blackpool generally experiences a higher level of movement in and out of the area, leading to regular and expected fluctuations in the number of children eligible. • Brent - Increased vaccine coverage has been attributed to increased activity in call/recall for vaccinations • Bromley - 3 GP practices have not submitted data for March.

	• Bury - Data cleansing between GPs and the CHIS system may have led to increases in vaccination coverages. • Camden - Two GP practices have not submitted data this quarter. • Cheshire West and Chester - There has been a change in data provider and CHIS system, leading to changes between Q3 and Q4. • City of London - City of London has been included in Hackney data. • Hampshire - The five year cohort is yet to have data validation take place. • Islington - One GP practice has not submitted data this quarter. • Lambeth - 2 GP practices have not submitted data for March. • Lewisham - 3 GP practices have not submitted data for February or March. • Middlesbrough - Ongoing validation work has resulted in changes to the number of children eligible. • North Tyneside - Data cleansing has been undertaken to update records of children moving out of the area, resulting in fluctuations in the number of eligible children listed. • Northumberland - Data cleansing has been undertaken to update records of children moving out of the area, resulting in fluctuations in the number of eligible children listed. • Southwark - 3 GP practices have not submitted data for March. • Stoke-on-Trent - Ongoing validation work has resulted in changes to the number of children eligible. • Westminster - Increased vaccine coverage has been attributed to increased activity in call/recall for vaccinations
2021 Jul-Sep Q2	• Bexley - "1 GP practice has not exported data for September • 1 GP practice has not exported data for the whole of quarter 2 • There was an amendment to the 12m CV1 data that arrived too late to be included in the body of the report. The amended figure for CV1 is 88.6%." • Blackburn with Darwen - A new CHIS provider has been in place serving Lancashire, Blackburn with Darwen and Blackpool, since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed early 2022 and will be reflected in quarter 3 COVER data. • Blackpool - A new CHIS provider has been in place serving Lancashire, Blackburn with Darwen and Blackpool, since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed early 2022 and will be reflected in quarter 3 COVER data. • Bromley - 1 GP practice has not exported data for September • Camden - 2 large GP practices have not exported data for the whole of quarter 3 • City of London - City of London has been included in Hackney data. • Greenwich - "4 GP practices have not exported data for September • 2 GP practices have not exported data for August and September • 1 GP practice has not exported data for the whole of quarter 2" • Lambeth - "3 GP practices have not exported data for September • 2 GP practices have not exported data for the whole of quarter 2" • Lancashire - A new CHIS provider has been in place serving Lancashire, Blackburn with Darwen and Blackpool, since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed early 2022 and will be reflected in quarter 3 COVER data • Lewisham - "2 GP practices have not exported data for September • 2 GP practices have not exported data for the whole of quarter 2"

	• North Northamptonshire - The data could not be provided separately for North and West Northamptonshire, therefore the combined data has been recorded under West Northamptonshire only. • North Yorkshire - 4 GP practices have not returned data for the whole of quarter 2 • Southwark - "1 GP practice has not exported data for September • 1 GP practice has not exported data for August and September" • West Northamptonshire - The data could not be provided separately for North and West Northamptonshire, therefore the combined data has been recorded under West Northamptonshire only.
2021 Oct-Dec Q3	• Bexley - "2 GP practices have not exported data for December • Blackburn with Darwen - A new CHIS provider has been in place since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed in early 2022 and is already showing improvements in quarter 3 data • Blackpool - A new CHIS provider has been in place since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed in early 2022 and is already showing improvements in quarter 3 data • Bromley - "2 GP practices have not exported data for December • Camden - 2 large GP practices have not exported data for the whole of quarter 3 • City of London - City of London has been included in Hackney data. • Greenwich - 2 GP practices have not exported data for the whole of quarter 3 • Lambeth - 2 GP practices have not exported data for the whole of quarter 3 • Lancashire - A new CHIS provider has been in place since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed in early 2022 and is already showing improvements in quarter 3 data • Lewisham - 2 GP practices have not exported data for the whole of quarter 3 • Southwark - "1 GP practice has not exported data for December • 2 GP practices have not exported data for November and December"
2021 Jan-Mar Q4	• Barking and Dagenham - 3 GP practices have not submitted any data for Quarter 4 • Bexley - 3 GP practices have not exported data for March. • Blackburn with Darwen - A new CHIS provider has been in place for Lancashire since February 2021. Commissioners are working closely with the provider to work on historic data quality issues. There is a full action plan in place to support them in resolving this and improve data quality. • Blackpool - A new CHIS provider has been in place for Lancashire since February 2021. Commissioners are working closely with the provider to work on historic data quality issues. There is a full action plan in place to support them in resolving this and improve data quality. • Bromley - "2 GP practices have not exported data for March • 1 GP practice has not exported data for February and March. • 1 GP practice has not exported data for the whole of Quarter 4. • Camden - 2 large GP practices have not submitted data for the whole of Quarter 4. • City of London - City of London has been included in Hackney data. • Greenwich - "3 GP practices have not exported data for March. • 1 GP practice has not exported data for the whole of Quarter 4. " • Isle of Wight - There has been a change of CHIS provider this quarter. • Lancashire - A new CHIS provider has been in place for Lancashire since February 2021. Commissioners are working closely with the provider to work on historic data

	quality issues. There is a full action plan in place to support them in resolving this and improve data quality. • Lambeth - "1 GP practice has not exported data for March. • 2 GP practices have not exported data for February and March. • 2 GP practices have not exported data for the whole of Quarter 4. " • Lewisham - "1 GP practice has not exported data for March • 1 GP practice have not exported data for February and March • 1 GP practices has not exported data for the whole of Quarter 4. " • Portsmouth - There has been a change of CHIS provider this quarter. • Southampton - There has been a change of CHIS provider this quarter. The data for 24m Hib/Men C has been excluded, because a data migration issue has undermined the accuracy.
2022 Apr- Jun Q1	• Bexley - There has been a change in the data linkage provider and this may have affected the data this quarter • Bromley - There has been a change in the data linkage provider and this may have affected the data this quarter • City of London - City of London has been included in Hackney data. • Croydon - There has been a change in the data linkage provider and this may have affected the data this quarter • Greenwich - There has been a change in the data linkage provider and this may have affected the data this quarter • Kingston Upon Thames - There has been a change in the data linkage provider and this may have affected the data this quarter • Lambeth - There has been a change in the data linkage provider and this may have affected the data this quarter • Lewisham - There has been a change in the data linkage provider and this may have affected the data this quarter • Merton - There has been a change in the data linkage provider and this may have affected the data this quarter • Richmond Upon Thames - There has been a change in the data linkage provider and this may have affected the data this quarter • Southwark - There has been a change in the data linkage provider and this may have affected the data this quarter • Sutton - There has been a change in the data linkage provider and this may have affected the data this quarter • Wandsworth - There has been a change in the data linkage provider and this may have affected the data this quarter • West Sussex - 1 GP practice did not provide data
2022 Jul- Sep Q2	• Bexley - Data cleansing and increased GP data collections from monthly to daily due to the olio campaign have improved coverage. • Camden - 2 GP practices did not provide data • City of London - City of London has been included in Hackney data • Greenwich - Data cleansing and increased GP data collections from monthly to daily due to the olio campaign have improved coverage. • Hackney - There is a data coding issue for 24 month Hib/MenC • Hampshire - Data from some EMIS practices is lower due to download problems and not all practices returning data.

	• Lambeth - Data cleansing and increased GP data collections from monthly to daily due to the olio campaign have improved coverage. • Lewisham - Data cleansing and increased GP data collections from monthly to daily due to the olio campaign have improved coverage. • Southampton - Data from some EMIS practices is lower due to download problems and not all practices returning data. • West Sussex - 1 GP practice did not provide data
2022 Oct-Dec Q3	• Bury - The increase in performance is in part be due to processes that have been put in place prior to the submission of COVER. The Immunisation Failsafe Team work with GP practices to ensure that any missing information is obtained prior to the report being run. This process has now been put in place across all eight of the CHIS localities supported by the Northern Care Alliance NHS Foundation Trust as part of the ongoing COVER improvement work. • City of London - City of London has been included in Hackney data • Kingston Upon Thames - Coding errors for DTaP/IPV/Hib/HepB and CV, MMR1 and HibMenC have been flagged which would have potentially effected previous COVER. • Lambeth - Decline in 3 month completeness for BCG due to an IT issue, CHIS have not received the data. Data is now being sent for vaccinations given in December and January and the backlog of data since July 2022 is in the process of being added to the provider's system • Southwark - Decline in 3 month completeness for BCG due to an IT issue, CHIS have not received the data. Data is now being sent for vaccinations given in Dec and Jan and the backlog of data since July 2022 is in the process of being added to the provider's system • Trafford - The increase in performance is in part be due to processes that have been put in place prior to the submission of COVER. The Immunisation Failsafe Team work with GP practices to ensure that any missing information is obtained prior to the report being run. This process has now been put in place across all eight of the CHIS localities supported by the Northern Care Alliance NHS Foundation Trust as part of the ongoing COVER improvement work.
2023 Jan-Mar Q4	• Barking and Dagenham - Coding issues with data linkage supplier • Blackburn with Darwen - A new CHIS provider has been in place since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed in early 2022 and is already showing improvements in quarter 3 data • Blackpool - A new CHIS provider has been in place since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed in early 2022 and is already showing improvements in quarter 3 data • Camden - 2 GP practices did not provide data • City of London - City of London has been included in Hackney data. • Hackney - 3 GP practices did not provide data • Haringey - 1 GP practice did not provide data • Havering - Coding issues with data linkage supplier • Kent - The CHIS have carried out a large data cleansing exercise since the previous report. • Lancashire - A new CHIS provider has been in place since February 2021. NHSEI has commissioned a data quality exercise to improve historic data quality which will be completed in early 2022 and is already showing improvements in quarter 3 data

	• Manchester - A longstanding audit on immunisation data was temporarily stood down over this quarter but has since restarted. • Medway - The CHIS have carried out a large data cleansing exercise since the previous report. • Redbridge - 10 GP practices did not provide data and coding issues with data linkage supplier • Waltham Forest - 3 GP practices did not provide data
2023 Apr-Jun Q1	• City of London - City of London has been included in Hackney data • North Northamptonshire - 1 GP practice has not exported data for the whole quarter • North Yorkshire - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs • Southend-on-Sea - There has been a catch-up program run in the Southend area and this is likely the cause of the rise in their figures • West Sussex - 1 GP practice has not exported data for the whole quarter • York - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs
2023 July-Sep Q2	• City of London - City of London has been included in Hackney data • North Northamptonshire - There was an issue with the data submitted for the LA collection, therefore the LA data was re-created using the data submitted for the GP collection. • North Yorkshire - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs • Southend-on-Sea - • West Sussex - • York - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs
2023 Oct-Dec Q3	• City of London - City of London has been included in Hackney data • North Northamptonshire - • North Yorkshire - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs • York - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs
2024 Jan-March Q4	• City of London - City of London has been included in Hackney data • Hammersmith and Fulham - A small number of practices are encountering difficulties in providing electronic immunisation data for uploading. • Kensington and Chelsea - A small number of practices are encountering difficulties in providing electronic immunisation data for uploading. • North Yorkshire - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs • Surrey - Improved data flows from GP practices have produced increases in coverage. • York - There may be some slight under-reporting due to unrecognisable codes from EMIS GPs

Appendix 4.4 Formula for segmented regression with a three-way interaction between region, deprivation, and COVID-19.

$$\begin{aligned}
Uptake_{LA,t} = & a_0 + \beta_1 t_1 + \beta_2 t_2 + \beta_3 t_3 + \sum_{i=2}^9 (\beta_{Ri} regionIDFac_i) + \beta_4 DepQuint_1 * t_1 + \beta_5 DepQuint_2 \\
& * t_1 + \beta_6 DepQuint_4 * t_1 + \beta_7 DepQuint_5 * t_1 + \beta_8 DepQuint_1 * t_2 + \beta_9 DepQuint_2 \\
& * t_2 + \beta_{10} DepQuint_4 * t_2 + \beta_{11} DepQuint_5 * t_2 + \beta_{12} DepQuint_1 * t_3 + \beta_{13} DepQuint_3 \\
& * t_3 + \beta_{14} DepQuint_4 * t_3 + \beta_{15} DepQuint_5 * t_3 \\
& + \sum_{i=2}^9 (\beta_{16i} DepQuint_1 * t_1 * regionIDFac_i + \beta_{17i} DepQuint_2 * t_1 + \beta_{18i} DepQuint_4 * t_1 \\
& * regionIDFac_i + \beta_{19i} DepQuint_5 * t_1 * regionIDFac_i) \\
& + \sum_{i=2}^9 (\beta_{20i} DepQuint_1 * t_2 * regionIDFac_i + \beta_{21i} DepQuint_2 * t_2 + \beta_{22i} DepQuint_4 * t_2 \\
& * regionIDFac_i + \beta_{23i} DepQuint_5 * t_2 * regionIDFac_i) \\
& + \sum_{i=2}^9 (\beta_{24i} DepQuint_1 * t_3 * regionIDFac_i + \beta_{25i} DepQuint_2 * t_3 + \beta_{26i} DepQuint_4 * t_3 \\
& * regionIDFac_i + \beta_{27i} DepQuint_5 * t_3 * regionIDFac_i) + u_{LA} + \varepsilon_{LA,t}
\end{aligned}$$

Where $Uptake_{LA,t}$ is the proportion of eligible children vaccinated in a local authority LA at time t . a_0 is the constant term, and t_1 , t_2 , and t_3 are the piecewise terms representing the quarterly trends from the first lockdown, phase one COVID-19 vaccination rollout, and phase two, respectively. $DepQuint_1$, $DepQuint_2$, $DepQuint_4$, and $DepQuint_5$ indicate the deprivation quintile of LA according to the 2019 Indices of Multiple Deprivation. $regionIDFac_i$ is the regional indicator, excluding the reference category (London). u_{LA} and $\varepsilon_{LA,t}$ are both error terms. u_{LA} is the local authority time invariant local error term, and $\varepsilon_{LA,t}$ is the idiosyncratic random error term. The model includes main effects of the three piecewise terms, t_1 , t_2 , and t_3 , but not for $DepQuint$, this is because they are absorbed by the panel structure. One control variable is also implemented, $nChild$; the number of vaccination-eligible children in a given local authority at each time point. This inclusion controls for population size effects.

Appendix 4.5 Table of summary statistics for annual COVER data.

		Six in One	Rotavirus	CV	MenB	Hib/Men C	MMR	Pre- school booster	Mean	SD	Min	Max
England	N	680,892	609,764	602,599	602,599	680,892	680,892	680,892				
	n	634,566	541,113	533,439	527,782	615,536	575,515	567,057				
	%	93.19628	88.74138	88.52305	87.58428	90.40141	84.52368	83.28149	88.035	3.119	83.281	93.196
North East	N	29,132	25,806	25,499	25,499	29,132	29,132	29,132				
	n	27,661	23,961	23,961	23,804	27,162	26,327	26,058				
	%	94.95057	92.8505	93.96839	93.35268	93.23768	90.37141	89.44803	92.597	1.825	89.448	94.950
North West	N	89,439	80,307	79,354	79,354	89,439	89,439	89,439				
	n	84,039	70,013	70,505	69,536	82,468	76,124	74,497				
	%	93.96237	87.18169	88.8487	87.62759	92.20586	85.11276	83.29364	88.318	3.4752	83.293	93.962
Yorkshire and the Humber	N	64,874	57,845	57,508	57,508	64,874	64,874	64,874				
	n	61,353	51,489	51,743	51,203	59,205	56,473	55,759				
	%	94.57256	89.01201	89.97531	89.03631	91.26152	87.05028	85.94969	89.55	2.6213	85.949	94.572
East Midlands	N	55,777	49,182	48,721	48,721	55,777	55,777	55,777				
	n	52,542	44,687	44,182	43,749	50,559	47,791	46,889				
	%	94.20012	90.86048	90.68369	89.79495	90.64489	85.68227	84.06512	89.418	3.180	84.065	94.200
West Midlands	N	74,414	66,103	66,487	66,487	74,414	74,414	74,414				
	n	69,515	58,401	58,703	57,931	67,906	62,297	61,591				
	%	93.41656	88.34849	88.29245	87.13132	91.25433	83.71677	82.76803	87.846	3.5141	82.768	93.416
East of England	N	75,971	66,803	66,803	66,803	75,971	75,971	75,971				
	n	71,733	61,748	60,589	59,822	69,245	66,762	65,958				
	%	94.42156	89.81789	90.69802	89.54987	91.14662	87.87827	86.81997	90.047	2.2736	86.819	94.421
London	N	120,955	111,812	109,422	109,422	120,955	120,955	120,955				

	n	106,581	94,400	87,975	86,829	101,690	89,471	87,905				
	%	88.11624	84.42743	80.39974	79.35242	84.07259	73.97048	72.67579	80.430	5.228	72.675	88.116
South East	N	110,007	96,967	96,276	96,276	110,007	110,007	110,007				
	n	103,445	87,991	87,174	86,746	100,878	95,985	94,918				
South West	%	94.03493	90.74324	90.54593	90.10138	91.70144	87.25354	86.2836	90.094	2.429	86.283	94.034
	N	60,323	52,994	52,529	52,529	60,323	60,323	60,323				
	n	57,697	48,423	48,607	48,162	56,423	54,285	53,482				
	%	95.64677	91.3745	92.53365	91.6865	93.5348	89.99055	88.65938	91.918	2.1239	88.659	95.646
Mean		93.70241	89.4018	89.54954	88.62589	91.00664	85.66959	84.440361				
SD		2.06359	2.376273	3.620939	3.734277	2.617204	4.607532	4.6770433				
Min		88.11624	84.42743	80.39974	79.35242	84.07259	73.97048	72.67579				
Max		95.64677	92.8505	93.96839	93.35268	93.5348	90.37141	89.44803				

Appendix 4.6 Table of summary statistics for the pre-school booster.

Region	2014 Sep	2014 Dec	2015 Mar	2015 Jun	2015 Sep	2015 Dec	2016 Mar	2016 Jun	2016 Sep	2016 Dec	2017 Mar	2017 Jun
North East	91.633%	93.027%	91.100%	92.175%	89.917%	90.567%	90.908%	90.025%	89.751%	89.984%	89.372%	89.160%
Yorkshire and the Humber	90.727%	90.520%	91.307%	90.907%	90.607%	90.573%	90.533%	89.960%	89.673%	89.494%	89.721%	89.841%
North West	89.830%	89.870%	88.909%	90.265%	90.235%	90.574%	90.409%	90.052%	89.136%	89.342%	89.066%	88.667%
East Midlands	88.122%	88.156%	88.678%	88.456%	87.856%	87.311%	88.422%	88.578%	88.031%	87.692%	87.278%	87.171%
West Midlands	89.286%	88.807%	90.679%	90.807%	89.914%	90.036%	88.900%	86.743%	87.978%	87.198%	86.765%	86.933%
South West	89.651%	90.201%	90.745%	90.651%	91.075%	91.467%	90.743%	91.271%	90.860%	90.375%	91.278%	90.991%
South East	84.242%	84.268%	85.489%	84.589%	85.350%	85.079%	83.468%	83.611%	83.768%	84.699%	85.226%	84.624%
East of England	88.791%	87.818%	88.782%	88.255%	88.109%	88.000%	87.464%	85.327%	85.576%	85.841%	86.550%	87.315%
London	76.546%	76.151%	75.831%	74.090%	75.034%	76.666%	74.759%	75.203%	69.188%	71.496%	72.780%	73.480%
England	0.87647	0.87646	0.87946	0.87799	0.87566	0.87808	0.87289	0.86752	0.85995	0.86235	0.86448	0.86464
	2017 Sep	2017 Dec	2018 Mar	2018 Jun	2018 Sep	2018 Dec	2019 Mar	2019 Jun	2019 Sep	2019 Dec	2020 Mar	2020 Jun
North East	88.985%	90.162%	90.738%	91.059%	90.990%	91.665%	90.982%	91.212%		90.205%	90.030%	89.962%
Yorkshire and the Humber	89.302%	89.389%	90.533%	90.123%	90.582%	89.862%	90.312%	89.626%		88.858%	88.378%	88.331%
North West	88.107%	87.474%	87.619%	87.941%	87.628%	87.407%	87.162%	86.806%		86.305%	86.123%	85.731%
East Midlands	87.478%	85.983%	86.028%	87.062%	87.125%	87.740%	87.849%	87.831%		85.590%	85.119%	86.138%
West Midlands	86.304%	86.163%	86.191%	87.024%	86.816%	86.037%	87.084%	86.539%		86.085%	85.701%	86.551%
South West	91.358%	90.217%	89.872%	89.993%	89.547%	90.926%	90.819%	88.216%		89.579%	88.646%	88.118%
South East	86.366%	87.262%	88.298%	88.363%	88.169%	88.902%	89.145%	88.734%		88.080%	87.564%	87.659%
East of England	86.595%	87.205%	87.931%	88.163%	88.209%	88.335%	89.315%	88.614%		88.118%	87.615%	87.345%
London	72.919%	71.990%	73.325%	73.007%	72.936%	72.085%	70.948%	71.184%		69.925%	71.206%	72.837%
England	0.86379	0.86205	0.86726	0.86970	0.86889	0.86995	0.87068	0.86529		0.85860	0.85597	0.85852

	2020 Sep	2020 Dec	2021 Mar	2021 Jun	2021 Sep	2021 Dec	2022 Mar	2022 Jun	Average	Min	Max	Range
North East	89.375%	89.129%	89.280%	87.813%	88.636%	88.489%	88.591%	89.153%	90.131%	87.813%	93.027%	5.214%
Yorkshire and the Humber	87.339%	87.261%	87.411%	86.836%	86.426%	85.874%	86.029%	86.463%	89.122%	85.874%	91.307%	5.433%
North West	84.792%	84.410%	84.984%	83.754%	82.913%	84.007%	83.924%	83.577%	87.323%	82.913%	90.574%	7.661%
East Midlands	85.240%	84.248%	84.109%	83.552%	84.011%	84.021%	84.479%	84.295%	86.569%	83.552%	88.678%	5.126%
West Midlands	84.211%	87.359%	85.233%	84.958%	83.806%	84.131%	84.020%	84.961%	86.878%	83.806%	90.807%	7.001%
South West	87.999%	87.598%	89.446%	89.329%	88.232%	89.341%	89.442%	89.902%	89.932%	87.598%	91.467%	3.869%
South East	86.655%	86.696%	86.806%	86.912%	85.841%	85.182%	86.239%	87.274%	86.276%	83.468%	89.145%	5.677%
East of England	86.662%	85.989%	85.813%	85.888%	85.123%	85.120%	85.227%	85.321%	87.110%	85.120%	89.315%	4.195%
London	68.732%	69.643%	73.461%	74.539%	72.529%	72.059%	72.758%	72.874%	72.909%	68.732%	76.666%	7.934%
England	0.84556	0.84703	0.85171	0.84842	0.84168	0.84247	0.84523	0.84868	0.86250	0.84168	0.87946	0.03778

Appendix 4.7 Table of summary statistics of pre-school booster uptake and deprivation quintile.

Deprivation IMD Quintile	2014 Sep	2014 Dec	2015 Mar	2015 Jun	2015 Sep	2015 Dec	2016 Mar	2016 Jun	2016 Sep	2016 Dec	2017 Mar	2017 Jun
Least deprived 20% (Quintile 5)	86.340%	86.463%	87.360%	85.977%	88.355%	86.993%	86.197%	86.670%	86.683%	86.115%	87.192%	87.125%
Quintile 4	86.925%	86.807%	87.479%	87.179%	87.168%	88.047%	86.701%	85.752%	84.383%	85.258%	85.601%	86.116%
Quintile 3	82.780%	82.759%	83.167%	83.643%	85.353%	84.653%	83.920%	83.407%	81.606%	82.361%	82.900%	82.731%
Quintile 2	87.930%	87.470%	87.473%	87.277%	85.840%	87.047%	86.997%	86.300%	84.994%	84.762%	85.142%	84.890%
Most deprived 20% (Quintile 1)	87.399%	87.318%	86.653%	86.653%	84.087%	86.083%	85.190%	85.047%	82.536%	84.308%	83.713%	83.905%
	2017 Sep	2017 Dec	2018 Mar	2018 Jun	2018 Sep	2018 Dec	2019 Mar	2019 Jun	2019 Sep	2019 Dec	2020 Mar	2020 Jun
Least deprived 20% (Quintile 5)	87.783%	86.854%	87.537%	87.293%	87.615%	88.764%	88.904%	87.970%		87.995%	87.092%	87.679%
Quintile 4	86.008%	84.847%	86.137%	86.216%	86.302%	85.833%	86.134%	86.070%		85.293%	85.250%	86.152%
Quintile 3	82.497%	82.477%	83.293%	83.957%	83.617%	83.666%	83.029%	82.752%		82.223%	83.301%	83.549%
Quintile 2	84.351%	85.549%	85.677%	85.768%	85.495%	85.399%	85.542%	85.264%		84.523%	84.354%	84.214%
Most deprived 20% (Quintile 1)	83.394%	83.240%	82.979%	83.563%	83.247%	82.467%	82.053%	81.254%		79.965%	79.620%	79.811%
	2020 Sep	2020 Dec	2021 Mar	2021 Jun	2021 Sep	2021 Dec	2022 Mar	2022 Jun	Average	Min	Max	Range
Least deprived 20% (Quintile 5)	86.808%	86.052%	87.350%	87.445%	87.158%	86.778%	87.669%	87.993%	86.789%	85.977%	88.355%	2.379%
Quintile 4	84.154%	84.379%	85.473%	85.469%	84.489%	84.615%	84.967%	84.901%	86.451%	84.383%	88.047%	3.664%
Quintile 3	81.027%	81.963%	83.022%	83.091%	81.682%	81.776%	81.565%	82.400%	83.273%	81.606%	85.353%	3.748%
Quintile 2	83.029%	83.238%	83.866%	83.758%	82.693%	82.875%	83.138%	83.522%	86.343%	84.762%	87.930%	3.168%

Most deprived 20% (Quintile 1)	78.250%	78.928%	79.320%	78.413%	77.582%	77.854%	78.205%	78.330%	85.241%	82.536%	87.399%	4.863%
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Appendix 4.8 Table of summary statistics for the MMR vaccine.

Region	2014 Sep	2014 Dec	2015 Mar	2015 Jun	2015 Sep	2015 Dec	2016 Mar	2016 Jun	2016 Sep	2016 Dec	2017 Mar	2017 Jun
North East	90.967%	93.145%	92.392%	92.125%	91.658%	91.275%	91.908%	91.375%	91.262%	91.551%	91.411%	90.925%
Yorkshire and the Humber	90.560%	90.813%	91.367%	91.313%	91.053%	91.280%	91.280%	90.547%	90.695%	90.653%	90.621%	90.528%
North West	90.896%	90.735%	90.735%	90.826%	90.696%	90.565%	90.896%	90.261%	89.792%	89.203%	89.563%	89.405%
East Midlands	89.156%	88.622%	87.844%	89.178%	88.600%	87.989%	88.900%	89.122%	89.350%	88.536%	88.437%	88.211%
West Midlands	91.150%	90.779%	92.043%	91.757%	91.486%	91.536%	90.221%	88.493%	88.936%	88.264%	87.644%	88.103%
South West	90.916%	90.792%	91.827%	91.357%	92.130%	92.070%	91.628%	92.220%	91.937%	91.343%	92.619%	91.999%
South East	86.753%	87.237%	87.205%	86.100%	87.994%	87.616%	86.916%	87.274%	87.410%	87.767%	87.950%	87.435%
East of England	89.382%	89.091%	89.645%	89.200%	89.555%	89.382%	88.973%	88.473%	87.665%	86.937%	87.693%	88.458%
London	79.773%	78.432%	78.405%	76.877%	76.122%	76.009%	76.581%	77.175%	72.038%	74.402%	75.265%	76.095%
England	88.839%	88.850%	89.052%	88.748%	88.810%	88.636%	88.589%	88.327%	87.676%	87.629%	87.911%	87.906%

	2017 Sep	2017 Dec	2018 Mar	2018 Jun	2018 Sep	2018 Dec	2019 Mar	2019 Jun	2019 Sep	2019 Dec	2020 Mar	2020 Jun
North East	90.519%	90.835%	91.587%	92.841%	92.062%	92.528%	91.718%	92.015%		91.589%	91.324%	91.409%
Yorkshire and the Humber	90.275%	90.186%	91.002%	90.619%	91.055%	90.745%	91.124%	90.518%		89.559%	89.372%	89.580%
North West	89.040%	88.639%	88.693%	88.587%	88.729%	88.572%	88.622%	88.433%		88.155%	87.739%	87.446%
East Midlands	88.704%	87.697%	88.454%	88.170%	88.369%	89.178%	89.603%	89.088%		86.904%	86.423%	87.083%
West Midlands	87.477%	87.099%	86.857%	87.828%	87.190%	86.748%	87.720%	87.320%		86.837%	86.525%	87.349%
South West	92.243%	92.224%	92.226%	92.175%	92.019%	92.329%	92.126%	90.490%		91.072%	91.508%	91.777%
South East	88.335%	88.669%	89.554%	89.710%	89.413%	89.933%	90.145%	89.757%		88.876%	88.624%	88.644%
East of England	87.994%	89.418%	90.180%	89.118%	89.453%	89.319%	89.877%	89.498%		88.991%	88.465%	88.089%
London	75.617%	74.829%	75.858%	75.583%	75.425%	74.637%	73.748%	73.761%		72.719%	73.503%	74.725%
England	87.801%	87.733%	88.268%	88.292%	88.191%	88.221%	88.298%	87.876%		87.189%	87.054%	87.345%

	2020 Sep	2020 Dec	2021 Mar	2021 Jun	2021 Sep	2021 Dec	2022 Mar	2022 Jun	Average	Min	Max	Range
North East	90.847%	90.388%	90.723%	89.302%	89.623%	89.269%	89.739%	90.307%	91.246%	89.269%	93.145%	3.876%
Yorkshire and the Humber	88.395%	88.292%	88.260%	87.986%	87.433%	86.767%	87.182%	87.365%	89.885%	86.767%	91.367%	4.599%
North West	86.616%	85.864%	86.791%	85.570%	84.952%	85.768%	85.515%	85.643%	88.482%	84.952%	90.896%	5.943%
East Midlands	85.988%	85.318%	86.423%	85.174%	84.927%	84.888%	85.832%	85.872%	87.679%	84.888%	89.603%	4.715%
West Midlands	85.121%	87.906%	85.988%	86.045%	84.882%	85.061%	85.079%	85.880%	87.914%	84.882%	92.043%	7.161%
South West	90.903%	91.170%	90.905%	90.360%	89.507%	90.407%	90.489%	90.740%	91.468%	89.507%	92.619%	3.112%
South East	87.725%	87.703%	87.642%	87.617%	87.018%	86.241%	87.255%	88.152%	88.022%	86.100%	90.145%	4.045%
East of England	87.517%	86.903%	87.053%	86.858%	85.987%	86.139%	86.451%	86.597%	88.334%	85.987%	90.180%	4.193%
London	71.112%	71.568%	73.855%	75.012%	72.820%	72.502%	73.347%	73.462%	74.879%	71.112%	79.773%	8.661%
England	86.025%	86.124%	86.405%	85.992%	85.239%	85.227%	85.654%	86.002%	87.545%	85.227%	89.052%	3.825%

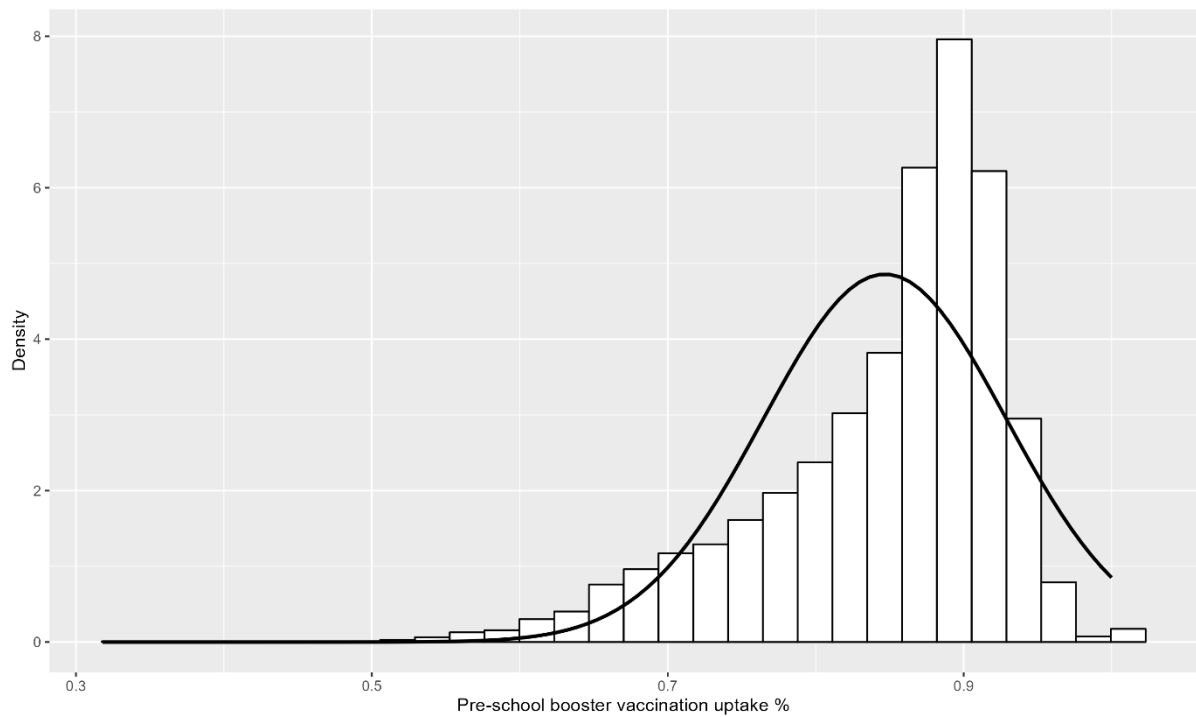
Appendix 4.9 Table of summary statistics of MMR vaccine uptake and deprivation.

Deprivation IMD Quintile	2014 Sep	2014 Dec	2015 Mar	2015 Jun	2015 Sep	2015 Dec	2016 Mar	2016 Jun	2016 Sep	2016 Dec	2017 Mar	2017 Jun
Least deprived 20% (Quintile 5)	88.090%	87.920%	88.297%	88.040%	88.659%	86.827%	88.027%	88.273%	88.860%	87.997%	88.551%	88.689%
Quintile 4	88.988%	88.562%	88.954%	88.528%	88.458%	88.891%	88.251%	87.710%	86.084%	87.249%	87.463%	87.832%
Quintile 3	84.510%	84.566%	85.037%	84.197%	85.480%	84.873%	84.737%	84.610%	82.643%	83.319%	83.501%	83.599%
Quintile 2	88.893%	88.433%	88.920%	88.073%	88.390%	88.577%	88.630%	88.257%	87.486%	86.769%	87.707%	87.132%
Most deprived 20% (Quintile 1)	88.422%	88.384%	87.949%	87.792%	85.860%	86.903%	86.390%	86.350%	84.241%	85.249%	85.197%	85.480%
	2017 Sep	2017 Dec	2018 Mar	2018 Jun	2018 Sep	2018 Dec	2019 Mar	2019 Jun	2019 Sep	2019 Dec	2020 Mar	2020 Jun
Least deprived 20% (Quintile 5)	89.382%	88.922%	89.581%	89.357%	89.637%	90.102%	90.416%	89.969%		89.303%	89.263%	89.917%
Quintile 4	87.675%	86.515%	87.569%	87.403%	87.580%	87.295%	87.298%	87.358%		86.926%	86.684%	87.347%
Quintile 3	83.497%	83.349%	84.104%	84.880%	84.747%	84.471%	83.897%	83.955%		83.614%	84.413%	84.665%
Quintile 2	86.448%	87.886%	87.873%	87.432%	87.197%	87.300%	87.400%	86.750%		86.005%	85.955%	86.030%
Most deprived 20% (Quintile 1)	84.847%	84.539%	84.485%	84.931%	84.308%	83.842%	83.774%	82.894%		81.769%	81.195%	81.361%
	2020 Sep	2020 Dec	2021 Mar	2021 Jun	2021 Sep	2021 Dec	2022 Mar	2022 Jun	Average	Min	Max	Range
Least deprived 20% (Quintile 5)	88.700%	88.447%	88.639%	88.233%	88.118%	87.664%	88.712%	89.067%	88.186%	86.827%	88.860%	2.033%
Quintile 4	85.426%	85.780%	86.660%	86.456%	85.596%	85.626%	85.890%	85.838%	88.081%	86.084%	88.988%	2.904%
Quintile 3	82.298%	82.860%	83.867%	84.023%	82.338%	82.390%	82.506%	83.166%	84.256%	82.643%	85.480%	2.837%
Quintile 2	84.973%	84.632%	84.933%	84.957%	83.763%	83.913%	84.367%	84.813%	88.106%	86.769%	88.920%	2.151%

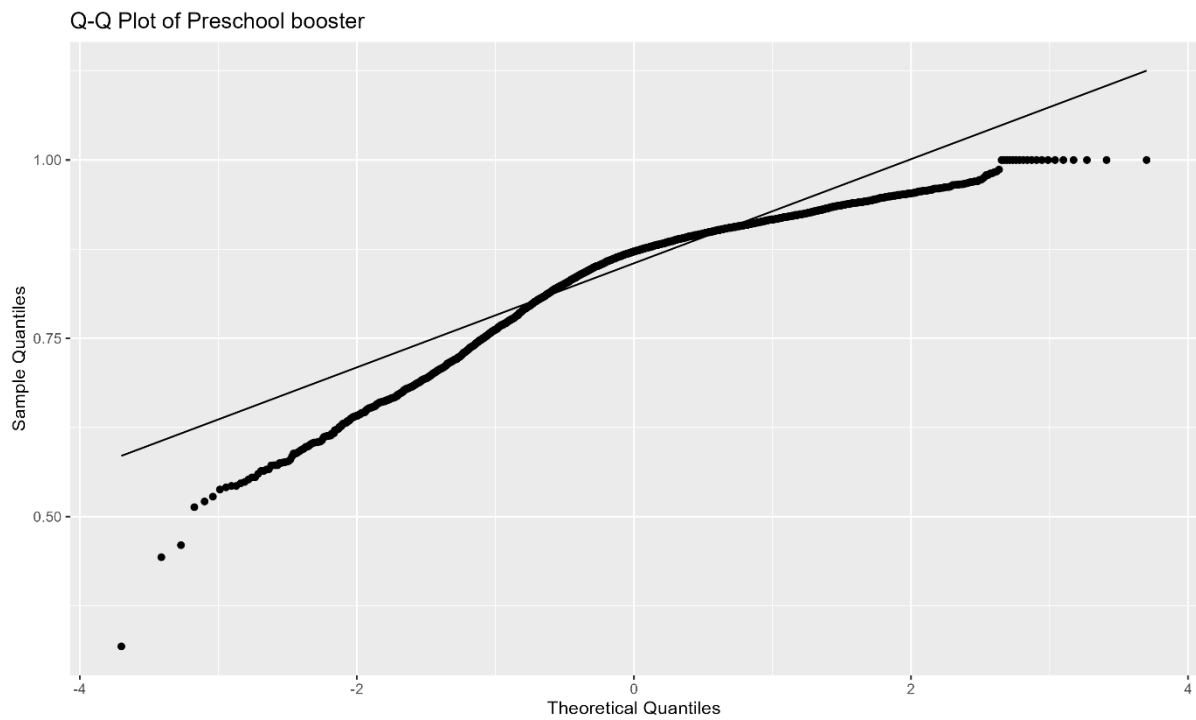
Most deprived
20% (Quintile
1)

80.017% 80.363% 80.496% 79.886% 79.039% 79.158% 79.467% 79.731% 86.518% 84.241% 88.422% 4.180%

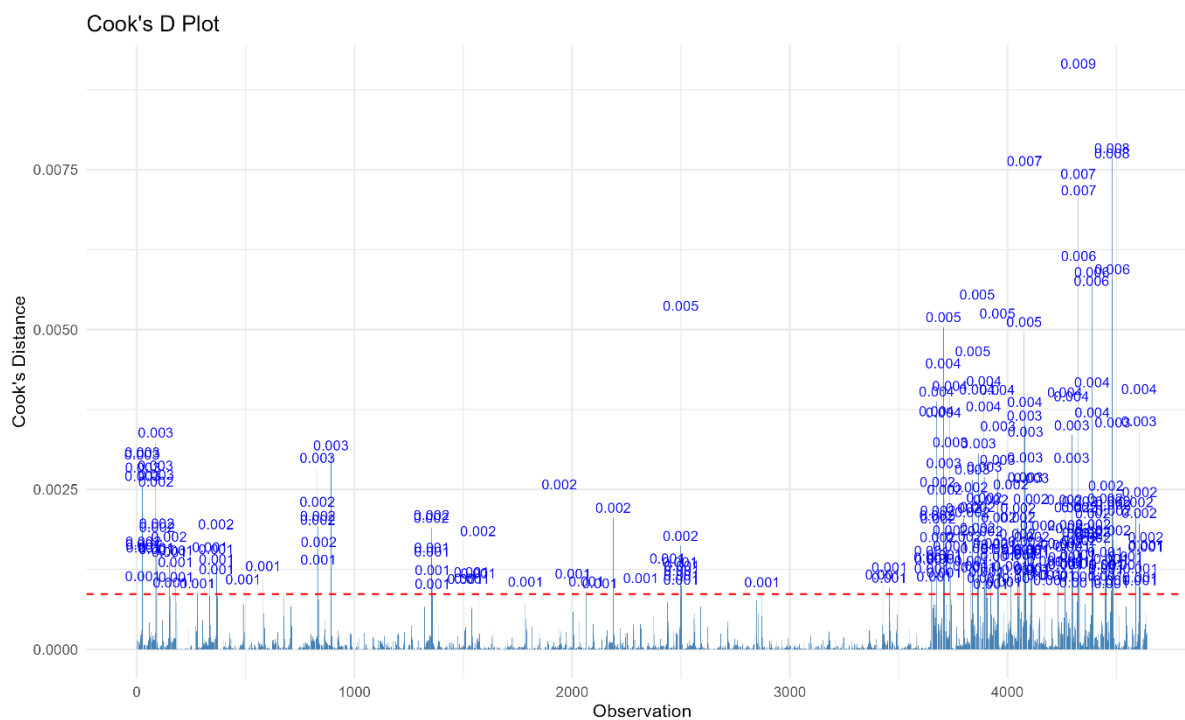
Appendix 4.10 Density plot for pre-school booster.



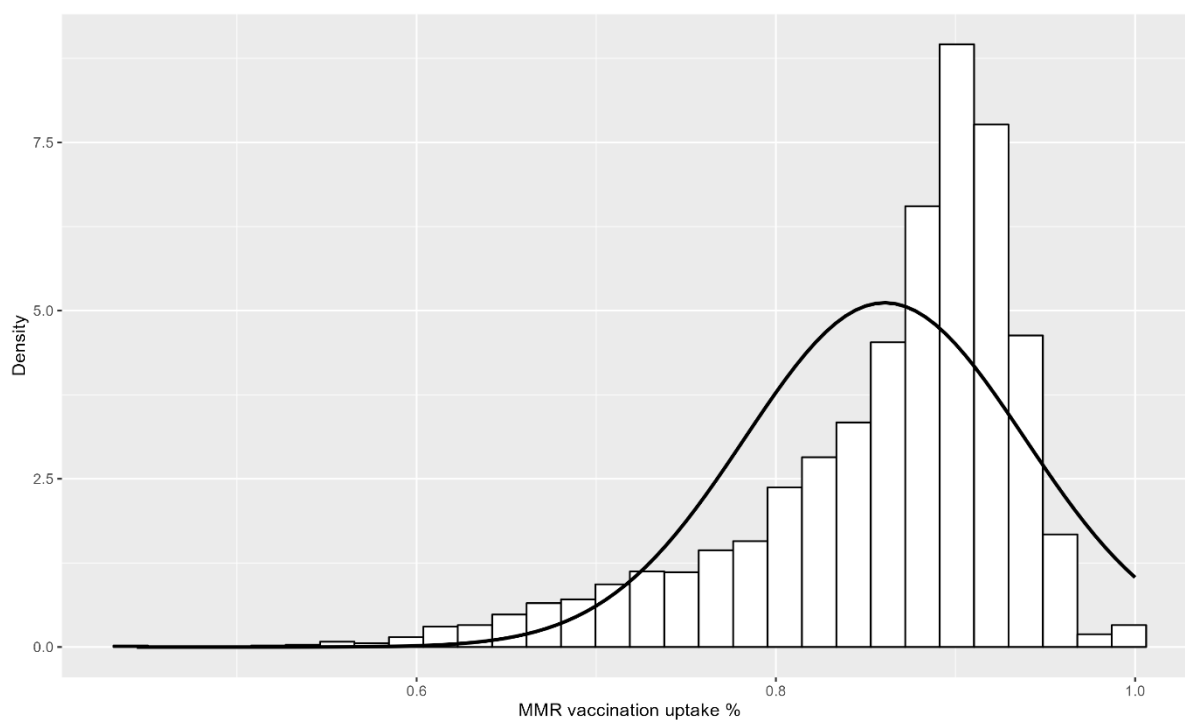
Appendix 4.11 Q-Q plot for pre-school booster.



Appendix 4.12 Cook's Distance plot for pre-school booster.

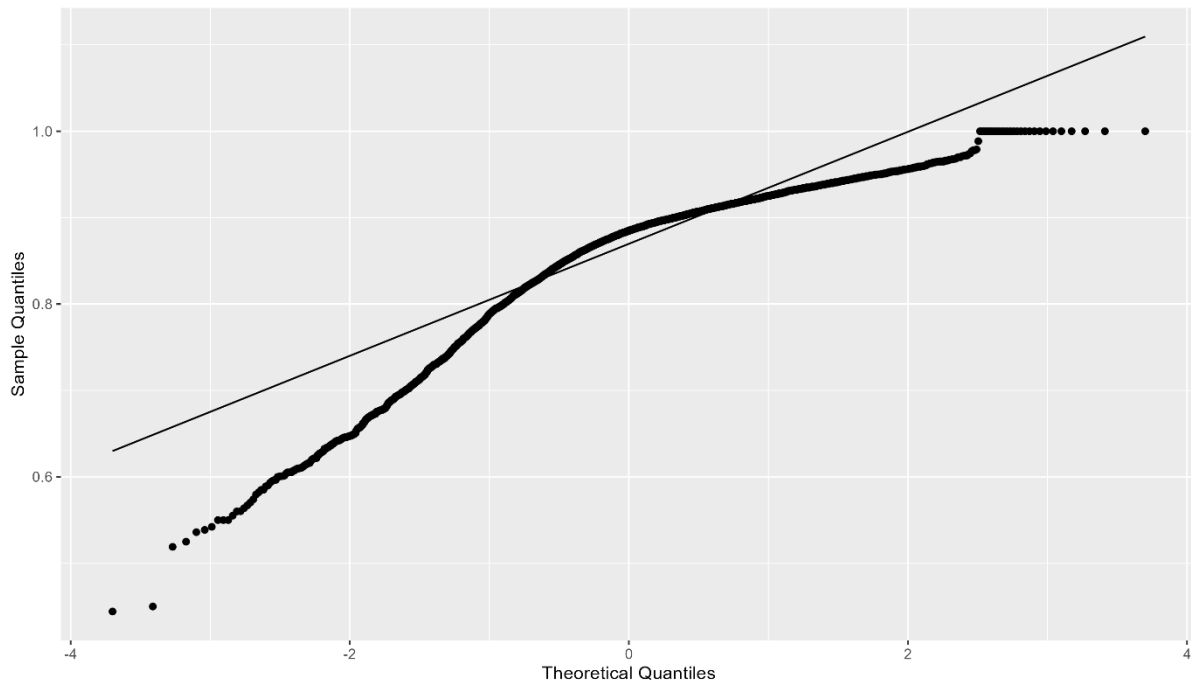


Appendix 4.13 Density plot for MMR vaccine.



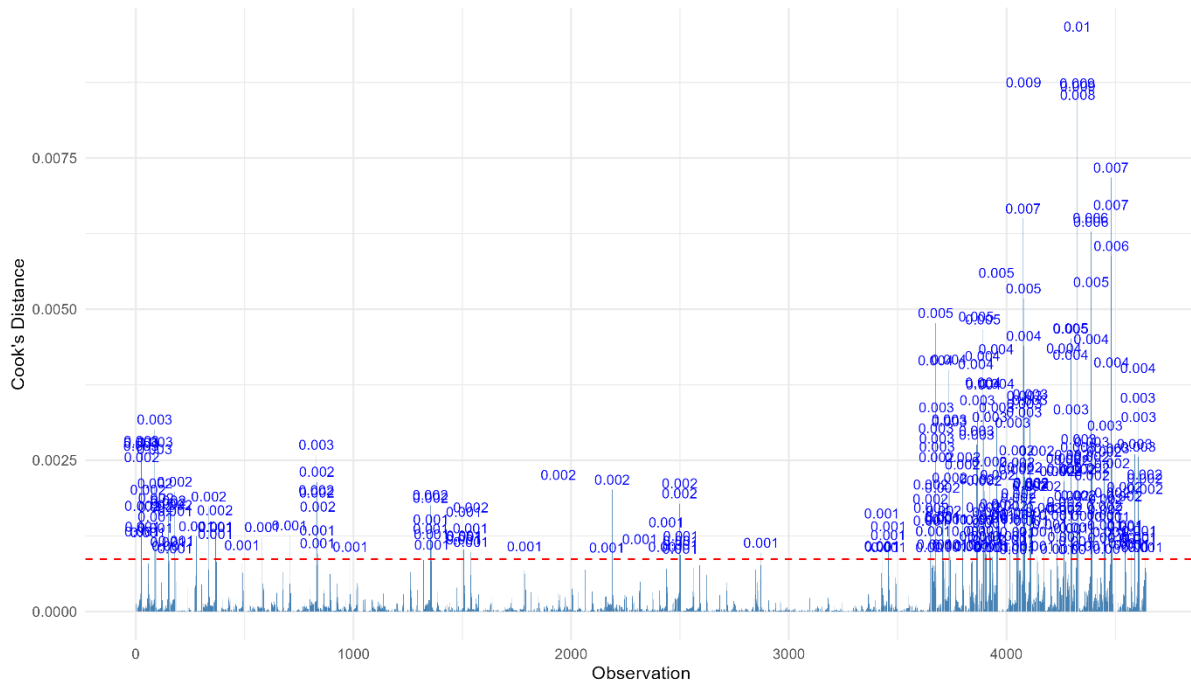
Appendix 4.14 Q-Q plot for MMR vaccine.

Q-Q Plot of MMR

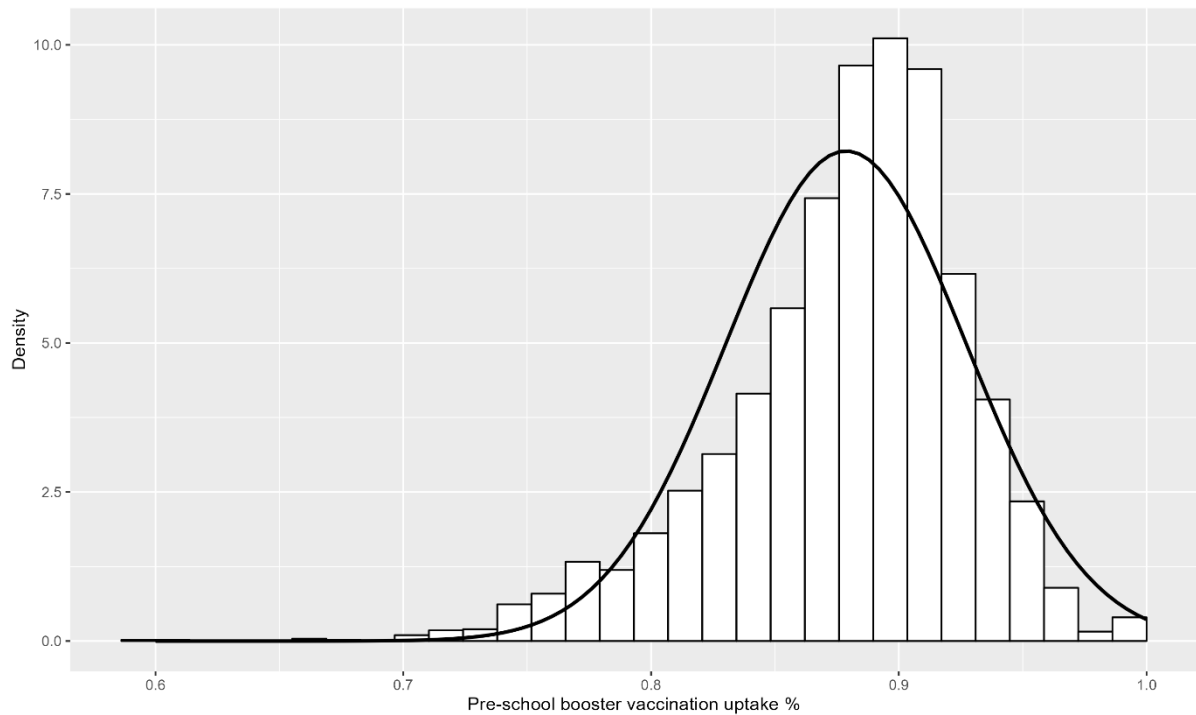


Appendix 4.15 Cook's distance for MMR vaccine.

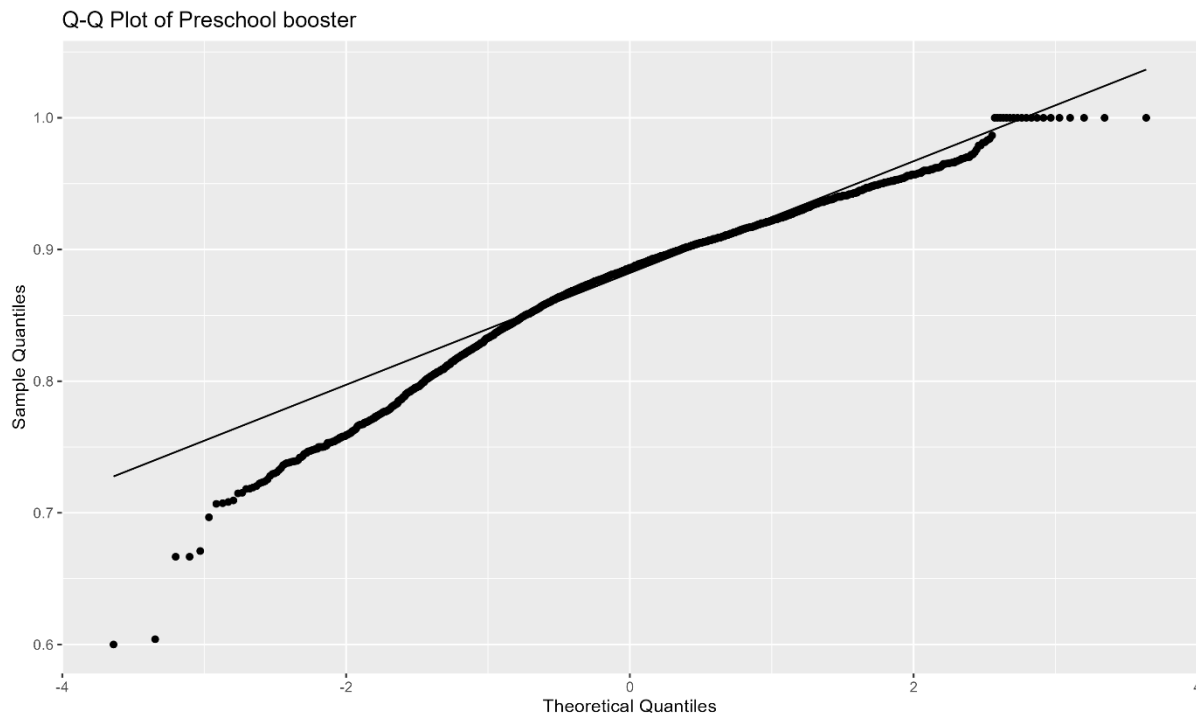
Cook's D Plot



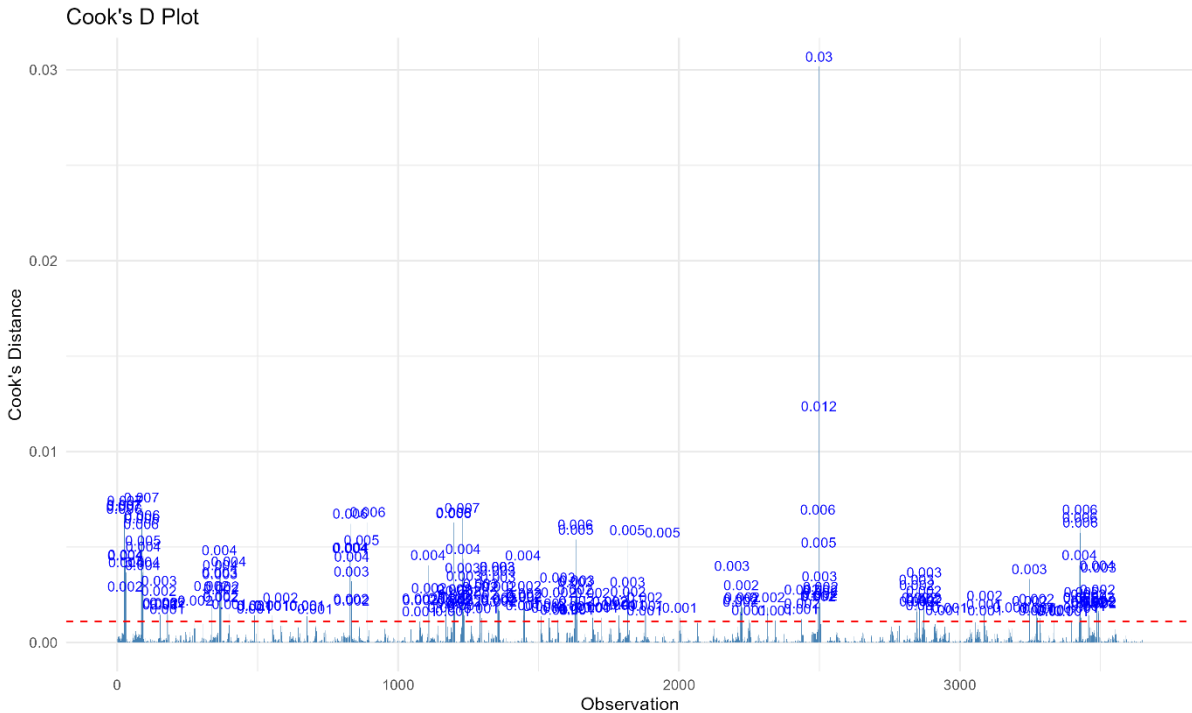
Appendix 4.16 Density plot pre-school booster without London.



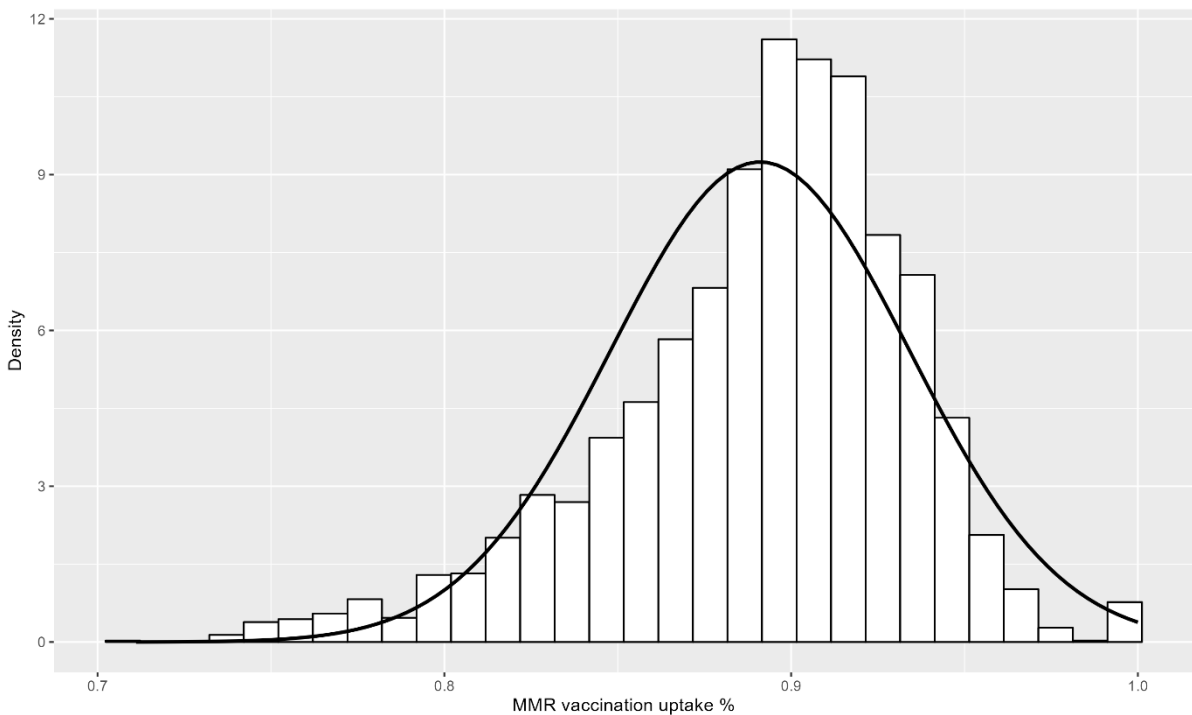
Appendix 4.17 Q-Q plot pre-school booster without London.



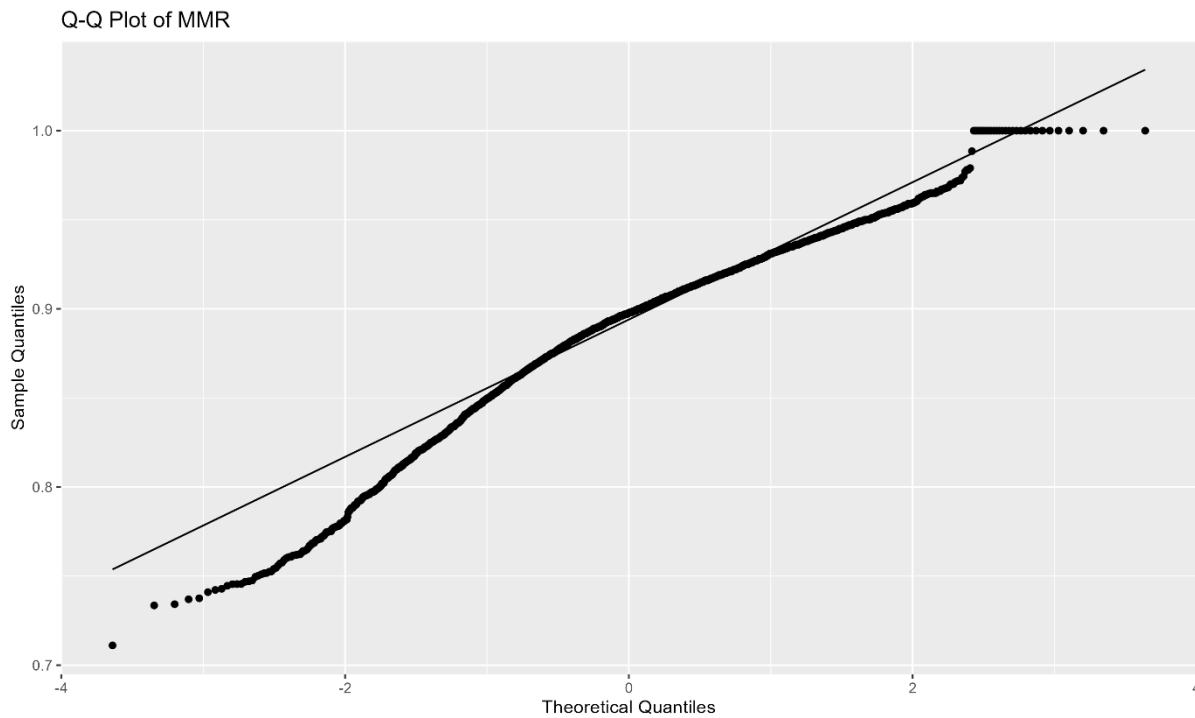
Appendix 4.18 Cook's Distance plot pre-school booster without London.



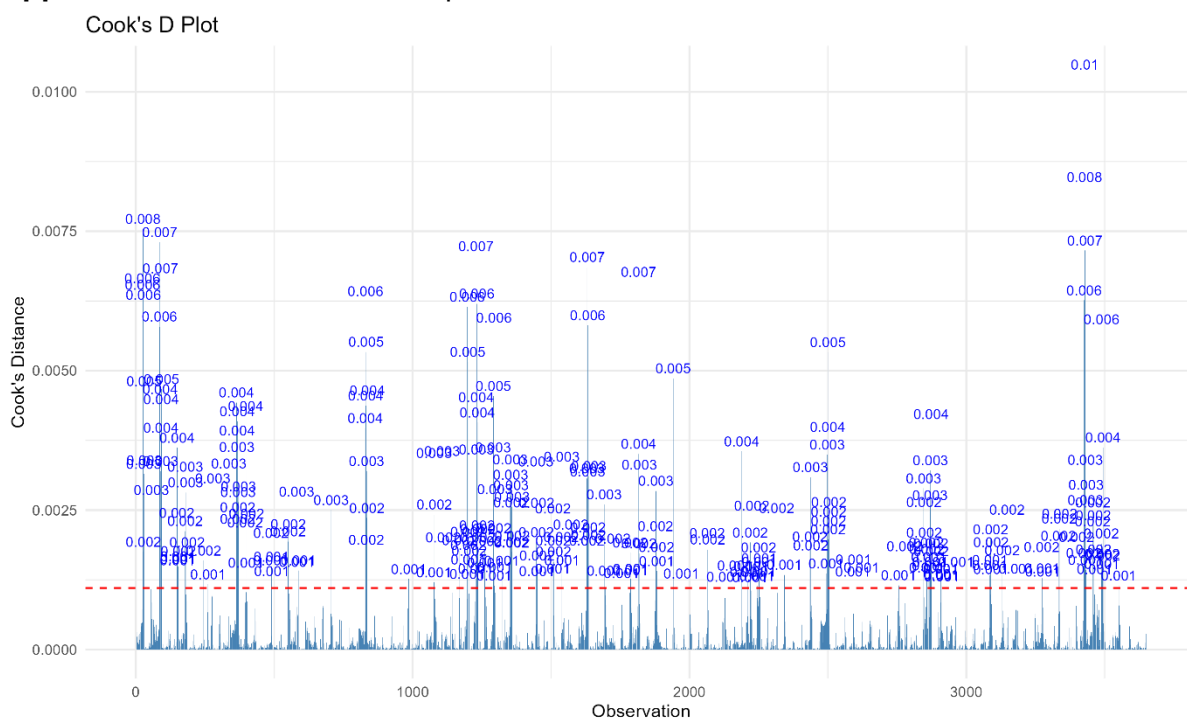
Appendix 4.19 Density plot MMR vaccine without London.



Appendix 4.20 Q-Q plot MMR vaccine without London.



Appendix 4.21 Cook's Distance plot MMR vaccine without London.



Appendix 4.22 Table of the results of a fixed effects linear piecewise regression analysing the pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of region, deprivation quintile and COVID-19 events.

Segmented regression of pre-school booster and MMR vaccine uptake, deprivation quintile, and region								
	Pre-school Booster				MMR Vaccine			
	estimate	95% CI			estimate	95% CI		
Lockdown (ref. London)								
Lockdown: North East	-0.080%	-0.183%	0.022%		-0.049%	-0.133%	0.036%	
Lockdown: Yorkshire and the Humber	-0.216%	-0.318%	-0.114%	***	-0.195%	-0.280%	-0.111%	***
Lockdown: North West	-0.096%	-0.192%	0.000%		-0.082%	-0.161%	-0.004%	*
Lockdown: East Midlands	-0.199%	-0.374%	-0.025%	*	-0.187%	-0.331%	-0.043%	*
Lockdown: West Midlands	-0.111%	-0.224%	0.002%		-0.122%	-0.215%	-0.029%	*
Lockdown: South West	0.113%	0.008%	0.218%	*	0.148%	0.062%	0.235%	**
Lockdown: South East	0.013%	-0.100%	0.125%		-0.027%	-0.120%	0.066%	
Lockdown: East of England	-0.093%	-0.206%	0.020%		-0.099%	-0.192%	-0.006%	*
Lockdown: Quintile 5 (ref. London, Quintile 3)								
Lockdown: Quintile 5: North East								
Lockdown: Quintile 5: Yorkshire and the Humber	0.284%	0.127%	0.441%	***	0.300%	0.170%	0.429%	***
Lockdown: Quintile 5: North West	-0.013%	-0.180%	0.154%		0.046%	-0.092%	0.184%	
Lockdown: Quintile 5: East Midlands	0.330%	0.108%	0.552%	**	0.257%	0.074%	0.440%	**
Lockdown: Quintile 5: West Midlands								
Lockdown: Quintile 5: South West	-0.238%	-0.382%	-0.093%	**	-0.053%	-0.172%	0.067%	
Lockdown: Quintile 5: South East	0.090%	-0.055%	0.235%		0.124%	0.004%	0.243%	*
Lockdown: Quintile 5: East of England	0.131%	-0.033%	0.295%		0.148%	0.013%	0.283%	*
Lockdown: Quintile 4 (ref. London, Quintile 3)								
Lockdown: Quintile 4: North East								
Lockdown: Quintile 4: Yorkshire and the Humber								
Lockdown: Quintile 4: North West	0.205%	0.057%	0.353%	**	0.217%	0.095%	0.338%	**
Lockdown: Quintile 4: East Midlands	0.219%	0.017%	0.422%		0.245%	0.079%	0.412%	**
Lockdown: Quintile 4: West Midlands	0.211%	0.063%	0.358%	**	0.229%	0.107%	0.351%	***

Lockdown: Quintile 4: South West	-0.061%	-0.203%	0.082%		-0.084%	-0.202%	0.033%	
Lockdown: Quintile 4: South East	0.074%	-0.085%	0.234%		0.052%	-0.080%	0.183%	
Lockdown: Quintile 4: East of England	0.185%	0.026%	0.345%	*	0.206%	0.074%	0.337%	**
Lockdown: Quintile 2 (ref. London, Quintile 3)								
Lockdown: Quintile 2: North East	0.208%	0.061%	0.355%	**	0.203%	0.082%	0.324%	**
Lockdown: Quintile 2: Yorkshire and the Humber	0.321%	0.178%	0.463%	***	0.346%	0.228%	0.463%	***
Lockdown: Quintile 2: North West	0.198%	0.055%	0.340%	**	0.223%	0.106%	0.341%	***
Lockdown: Quintile 2: East Midlands								
Lockdown: Quintile 2: West Midlands	0.213%	0.003%	0.422%	*	0.262%	0.089%	0.434%	**
Lockdown: Quintile 2: South West								
Lockdown: Quintile 2: South East	0.168%	0.013%	0.322%	*	0.174%	0.046%	0.301%	**
Lockdown: Quintile 2: East of England	0.153%	-0.021%	0.328%		0.101%	-0.043%	0.245%	
Lockdown: Quintile 1 (ref. London, Quintile 3)								
Lockdown: Quintile 1: North East	0.316%	0.171%	0.461%	***	0.296%	0.176%	0.415%	***
Lockdown: Quintile 1: Yorkshire and the Humber	0.332%	0.180%	0.484%	***	0.329%	0.204%	0.455%	***
Lockdown: Quintile 1: North West	0.093%	-0.033%	0.220%		0.140%	0.036%	0.244%	**
Lockdown: Quintile 1: East Midlands	0.178%	-0.040%	0.397%		0.192%	0.012%	0.372%	*
Lockdown: Quintile 1: West Midlands	0.259%	0.111%	0.407%	**	0.254%	0.132%	0.375%	***
Lockdown: Quintile 1: South West								
Lockdown: Quintile 1: South East								
Lockdown: Quintile 1: East of England								
Phase 1 Vaccination Rollout (ref. London)								
Phase 1: North East	-0.052%	-0.234%	0.129%		-0.001%	-0.151%	0.148%	
Phase 1: Yorkshire and the Humber	-0.039%	-0.220%	0.142%		0.019%	-0.131%	0.168%	
Phase 1: North West	-0.136%	-0.306%	0.033%		-0.076%	-0.215%	0.064%	
Phase 1: East Midlands	-0.019%	-0.328%	0.290%		0.052%	-0.202%	0.307%	
Phase 1: West Midlands	-0.098%	-0.297%	0.102%		-0.040%	-0.204%	0.125%	
Phase 1: South West	-0.138%	-0.325%	0.048%		-0.078%	-0.232%	0.075%	
Phase 1: South East	-0.096%	-0.296%	0.103%		-0.083%	-0.248%	0.081%	
Phase 1: East of England	-0.142%	-0.341%	0.058%		-0.082%	-0.246%	0.083%	
Phase 1: Quintile 5 (ref. London, Quintile 3)								

Phase 1: Quintile 5: North East						
Phase 1: Quintile 5: Yorkshire and the Humber	-0.191%	-0.469%	0.087%	-0.189%	-0.419%	0.040%
Phase 1: Quintile 5: North West	0.051%	-0.245%	0.346%	0.041%	-0.202%	0.284%
Phase 1: Quintile 5: East Midlands	-0.352%	-0.744%	0.041%	-0.146%	-0.469%	0.178%
Phase 1: Quintile 5: West Midlands						
Phase 1: Quintile 5: South West	0.152%	-0.107%	0.412%	-0.014%	-0.229%	0.200%
Phase 1: Quintile 5: South East	-0.059%	-0.316%	0.197%	-0.004%	-0.216%	0.207%
Phase 1: Quintile 5: East of England	-0.055%	-0.345%	0.236%	-0.024%	-0.263%	0.216%
Phase 1: Quintile 4 (ref. London, Quintile 3)						
Phase 1: Quintile 4: North East						
Phase 1: Quintile 4: Yorkshire and the Humber						
Phase 1: Quintile 4: North West	0.026%	-0.235%	0.288%	0.060%	-0.155%	0.276%
Phase 1: Quintile 4: East Midlands	-0.063%	-0.422%	0.295%	-0.065%	-0.360%	0.230%
Phase 1: Quintile 4: West Midlands	-0.066%	-0.327%	0.196%	-0.057%	-0.272%	0.159%
Phase 1: Quintile 4: South West	0.031%	-0.221%	0.283%	0.051%	-0.157%	0.258%
Phase 1: Quintile 4: South East	0.006%	-0.276%	0.288%	0.058%	-0.174%	0.291%
Phase 1: Quintile 4: East of England	0.025%	-0.257%	0.307%	0.027%	-0.206%	0.259%
Phase 1: Quintile 2 (ref. London, Quintile 3)						
Phase 1: Quintile 2: North East	-0.113%	-0.373%	0.147%	-0.110%	-0.324%	0.105%
Phase 1: Quintile 2: Yorkshire and the Humber	-0.109%	-0.361%	0.142%	-0.129%	-0.337%	0.078%
Phase 1: Quintile 2: North West	-0.022%	-0.274%	0.230%	-0.007%	-0.214%	0.201%
Phase 1: Quintile 2: East Midlands						
Phase 1: Quintile 2: West Midlands	-0.029%	-0.399%	0.342%	-0.024%	-0.330%	0.281%
Phase 1: Quintile 2: South West						
Phase 1: Quintile 2: South East	-0.087%	-0.360%	0.186%	-0.028%	-0.253%	0.198%
Phase 1: Quintile 2: East of England	-0.060%	-0.369%	0.249%	-0.006%	-0.260%	0.249%
Phase 1: Quintile 1 (ref. London, Quintile 3)						
Phase 1: Quintile 1: North East	-0.116%	-0.372%	0.140%	-0.077%	-0.289%	0.134%
Phase 1: Quintile 1: Yorkshire and the Humber	-0.091%	-0.361%	0.178%	-0.081%	-0.303%	0.141%
Phase 1: Quintile 1: North West	0.051%	-0.173%	0.274%	0.052%	-0.132%	0.236%
Phase 1: Quintile 1: East Midlands	-0.067%	-0.454%	0.319%	-0.078%	-0.397%	0.240%

Phase 1: Quintile 1: West Midlands	-0.045%	-0.306%	0.217%	-0.043%	-0.259%	0.173%
Phase 1: Quintile 1: South West						
Phase 1: Quintile 1: South East						
Phase 1: Quintile 1: East of England						
Phase 2 Vaccination Rollout (ref. London)						
Phase 2: North East	0.001%	-0.165%	0.166%	-0.025%	-0.161%	0.111%
Phase 2: Yorkshire and the Humber	-0.001%	-0.167%	0.164%	-0.015%	-0.152%	0.121%
Phase 2: North West	0.028%	-0.126%	0.183%	0.034%	-0.094%	0.161%
Phase 2: East Midlands	0.075%	-0.208%	0.357%	0.045%	-0.187%	0.278%
Phase 2: West Midlands	0.057%	-0.126%	0.239%	0.051%	-0.099%	0.202%
Phase 2: South West	-0.014%	-0.185%	0.156%	-0.017%	-0.158%	0.123%
Phase 2: South East	0.015%	-0.167%	0.197%	0.022%	-0.129%	0.172%
Phase 2: East of England	0.024%	-0.158%	0.207%	0.008%	-0.142%	0.158%
Phase 2: Quintile 5 (ref. London, Quintile 3)						
Phase 2: Quintile 5: North East						
Phase 2: Quintile 5: Yorkshire and the Humber	0.077%	-0.177%	0.331%	0.074%	-0.135%	0.284%
Phase 2: Quintile 5: North West	0.004%	-0.266%	0.274%	-0.009%	-0.231%	0.214%
Phase 2: Quintile 5: East Midlands	0.079%	-0.280%	0.437%	-0.069%	-0.365%	0.226%
Phase 2: Quintile 5: West Midlands						
Phase 2: Quintile 5: South West	0.063%	-0.176%	0.301%	0.013%	-0.183%	0.210%
Phase 2: Quintile 5: South East	-0.013%	-0.247%	0.222%	-0.017%	-0.210%	0.176%
Phase 2: Quintile 5: East of England	0.020%	-0.245%	0.285%	0.019%	-0.200%	0.238%
Phase 2: Quintile 4 (ref. London, Quintile 3)						
Phase 2: Quintile 4: North East						
Phase 2: Quintile 4: Yorkshire and the Humber						
Phase 2: Quintile 4: North West	-0.037%	-0.276%	0.202%	-0.094%	-0.291%	0.103%
Phase 2: Quintile 4: East Midlands	-0.135%	-0.462%	0.193%	-0.131%	-0.401%	0.139%
Phase 2: Quintile 4: West Midlands	-0.049%	-0.288%	0.190%	-0.064%	-0.261%	0.133%
Phase 2: Quintile 4: South West	0.016%	-0.214%	0.246%	-0.031%	-0.220%	0.159%
Phase 2: Quintile 4: South East	-0.042%	-0.300%	0.216%	-0.061%	-0.273%	0.152%
Phase 2: Quintile 4: East of England	-0.053%	-0.310%	0.205%	-0.058%	-0.271%	0.154%

Phase 2: Quintile 2 (ref. London, Quintile 3)

Phase 2: Quintile 2: North East	-0.004%	-0.242%	0.234%	0.019%	-0.177%	0.215%
Phase 2: Quintile 2: Yorkshire and the Humber	-0.032%	-0.262%	0.198%	0.006%	-0.184%	0.196%
Phase 2: Quintile 2: North West	-0.043%	-0.273%	0.187%	-0.051%	-0.241%	0.139%
Phase 2: Quintile 2: East Midlands						
Phase 2: Quintile 2: West Midlands	-0.161%	-0.500%	0.177%	-0.129%	-0.408%	0.150%
Phase 2: Quintile 2: South West						
Phase 2: Quintile 2: South East	0.021%	-0.228%	0.271%	0.021%	-0.184%	0.227%
Phase 2: Quintile 2: East of England	0.020%	-0.262%	0.302%	0.041%	-0.191%	0.274%

Phase 2: Quintile 1 (ref. London, Quintile 3)

Phase 2: Quintile 1: North East	0.006%	-0.228%	0.240%	-0.006%	-0.199%	0.187%
Phase 2: Quintile 1: Yorkshire and the Humber	-0.047%	-0.293%	0.199%	-0.047%	-0.250%	0.156%
Phase 2: Quintile 1: North West	-0.082%	-0.286%	0.122%	-0.106%	-0.274%	0.062%
Phase 2: Quintile 1: East Midlands	-0.099%	-0.452%	0.254%	-0.070%	-0.361%	0.221%
Phase 2: Quintile 1: West Midlands	-0.094%	-0.333%	0.145%	-0.084%	-0.281%	0.113%
Phase 2: Quintile 1: South West						
Phase 2: Quintile 1: South East						
Phase 2: Quintile 1: East of England						

Adjusted R² = 16.79%Adjusted R² = 22.24%* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Control variables: Number of vaccine-eligible children in a local authority each quarter.

Appendix 4.23 Table of the results of a fixed effects linear piecewise regression analysing the pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events (vaccination rollout Phase 1 not lagged).

Piecewise regression of vaccine uptake							
	Pre-school booster Adjusted R ² = 12.72%				MMR vaccination Adjusted R ² = 19.44%		
	estimate	95% CI			estimate	95% CI	
Time	-0.101%	-0.119%	-0.083%	***	-0.089%	-0.103%	-0.074% ***
Lockdown	0.000%	-0.039%	0.039%		0.004%	-0.028%	0.036%
<i>Lockdown: Least deprived 20% (Quintile 5)</i>	0.037%	-0.016%	0.090%		0.049%	0.006%	0.093% *
<i>Lockdown: Quintile 4</i>	-0.004%	-0.057%	0.049%		-0.025%	-0.069%	0.018%
<i>Lockdown: Quintile 2</i>	-0.053%	-0.106%	0.000%		-0.058%	-0.101%	-0.014% **
<i>Lockdown: Most deprived 20% (Quintile 1)</i>	-0.160%	-0.213%	-0.107%	***	-0.157%	-0.200%	-0.113% ***
Phase 1 Vaccination Rollout	0.029%	-0.020%	0.078%		0.013%	-0.027%	0.053%
<i>Phase 1: Least deprived 20% (Quintile 5)</i>	-0.027%	-0.096%	0.042%		-0.021%	-0.078%	0.035%
<i>Phase 1: Quintile 4</i>	-0.007%	-0.076%	0.062%		0.009%	-0.048%	0.065%
<i>Phase 1: Quintile 2</i>	-0.011%	-0.080%	0.058%		-0.023%	-0.079%	0.034%
<i>Phase 1: Most deprived 20% (Quintile 1)</i>	0.001%	-0.068%	0.070%		0.000%	-0.056%	0.057%
Phase 2 Vaccination Rollout	-0.016%	-0.054%	0.022%		-0.018%	-0.049%	0.013%
<i>Phase 2: Least deprived 20% (Quintile 5)</i>	0.035%	-0.019%	0.088%		0.002%	-0.042%	0.046%
<i>Phase 2: Quintile 4</i>	0.005%	-0.048%	0.059%		0.000%	-0.044%	0.043%
<i>Phase 2: Quintile 2</i>	0.013%	-0.041%	0.066%		0.015%	-0.029%	0.059%
<i>Phase 2: Most deprived 20% (Quintile 1)</i>	0.001%	-0.053%	0.054%		0.006%	-0.038%	0.050%

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Control variables: Number of vaccine-eligible children in a local authority each quarter.

Appendix 4.24 Table of the results of a fixed effects linear piecewise regression analysing the pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events, including more piecewise terms to model nonlinearity.

Piecewise regression of vaccine uptake							
	Pre-school booster Adjusted R ² = 19.97%				MMR vaccination Adjusted R ² = 19.58%		
	estimate	95% CI			estimate	95% CI	
Further non-linearity piecewise term	-0.080%	-0.140%	-0.020%	**	-0.034%	-0.084%	0.015%
Time	-0.008%	-0.080%	0.065%		-0.049%	-0.109%	0.010%
Lockdown	0.001%	-0.031%	0.033%		0.001%	-0.025%	0.027%
Lockdown: Least deprived 20% (Quintile 5)	0.023%	-0.020%	0.067%		0.045%	0.009%	0.080% *
Lockdown: Quintile 4	-0.007%	-0.050%	0.036%		-0.021%	-0.057%	0.014%
Lockdown: Quintile 2	-0.054%	-0.097%	-0.011%	*	-0.061%	-0.097%	-0.026% **
Lockdown: Most deprived 20% (Quintile 1)	-0.157%	-0.200%	-0.114%	***	-0.152%	-0.188%	-0.117% ***
Phase 1 Vaccination Rollout	0.041%	-0.013%	0.095%		0.031%	-0.014%	0.075%
Phase 1: Least deprived 20% (Quintile 5)	-0.003%	-0.080%	0.073%		-0.024%	-0.087%	0.039%
Phase 1: Quintile 4	-0.003%	-0.080%	0.073%		0.003%	-0.060%	0.065%
Phase 1: Quintile 2	-0.016%	-0.092%	0.061%		-0.030%	-0.093%	0.032%
Phase 1: Most deprived 20% (Quintile 1)	-0.007%	-0.084%	0.069%		-0.014%	-0.077%	0.049%
Phase 2 Vaccination Rollout	-0.034%	-0.083%	0.016%		-0.034%	-0.075%	0.006%
Phase 2: Least deprived 20% (Quintile 5)	0.024%	-0.046%	0.095%		0.009%	-0.048%	0.067%
Phase 2: Quintile 4	0.004%	-0.065%	0.074%		0.002%	-0.056%	0.059%
Phase 2: Quintile 2	0.019%	-0.051%	0.089%		0.026%	-0.031%	0.084%
Phase 2: Most deprived 20% (Quintile 1)	0.007%	-0.063%	0.076%		0.016%	-0.041%	0.073%

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Control variables: Number of vaccine-eligible children in a local authority each quarter.

Appendix 4.25 Table of the results of a fixed effects linear piecewise regression analysing the pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events (deprivation reference category quintile 1).

Piecewise regression of vaccine uptake								
Pre-school booster Adjusted R ² = 12.8%					MMR vaccination Adjusted R ² = 19.48%			
	estimate	95% CI			estimate	95% CI		
Time	-0.101%	-0.119%	-0.083%	***	-0.089%	-0.103%	-0.075%	***
Lockdown	-0.153%	-0.185%	-0.121%	***	-0.150%	-0.176%	-0.124%	***
<i>Lockdown: Least deprived 20% (Quintile 5)</i>	0.181%	0.137%	0.224%	***	0.197%	0.162%	0.232%	***
<i>Lockdown: Quintile 4</i>	0.150%	0.107%	0.193%	***	0.131%	0.096%	0.167%	***
<i>Lockdown: Quintile 3</i>	0.157%	0.114%	0.200%	***	0.152%	0.117%	0.188%	***
<i>Lockdown: Quintile 2</i>	0.103%	0.060%	0.146%	***	0.091%	0.056%	0.126%	***
Phase 1 Vaccination Rollout	0.034%	-0.020%	0.088%		0.017%	-0.027%	0.061%	
<i>Phase 1: Least deprived 20% (Quintile 5)</i>	0.004%	-0.073%	0.081%		-0.010%	-0.073%	0.053%	
<i>Phase 1: Quintile 4</i>	0.004%	-0.072%	0.081%		0.017%	-0.046%	0.079%	
<i>Lockdown: Quintile 3</i>	0.007%	-0.069%	0.084%		0.014%	-0.049%	0.077%	
<i>Lockdown: Quintile 2</i>	-0.008%	-0.085%	0.068%		-0.016%	-0.079%	0.046%	
Phase 2 Vaccination Rollout	-0.026%	-0.075%	0.023%		-0.018%	-0.058%	0.022%	
<i>Phase 2: Least deprived 20% (Quintile 5)</i>	0.017%	-0.053%	0.088%		-0.007%	-0.064%	0.051%	
<i>Phase 2: Quintile 4</i>	-0.002%	-0.072%	0.067%		-0.014%	-0.072%	0.043%	
<i>Lockdown: Quintile 3</i>	-0.007%	-0.077%	0.063%		-0.016%	-0.073%	0.041%	
<i>Lockdown: Quintile 2</i>	0.012%	-0.058%	0.082%		0.010%	-0.047%	0.068%	

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Control variables: Number of vaccine-eligible children in a local authority each quarter.

Appendix 4.26 24 Table of the results of a fixed effects polynomial piecewise regression analysing the pre-school booster and MMR vaccination uptake from July – September 2014 to April – June 2022 and the interaction effects of deprivation quintile and COVID-19 events.

Piecewise regression of vaccine uptake								
	Pre-school booster				MMR vaccination			
	Adjusted R ² = 12.749%				Adjusted R ² = 19.4%			
	<i>estimate</i>	<i>95% CI</i>			<i>estimate</i>	<i>95% CI</i>		
Time	-0.1015%	-0.1191%	-0.0839%	***	-0.0896%	-0.1040%	-0.0751%	***
Lockdown	0.0002%	-0.0012%	0.0015%		0.0001%	-0.0010%	0.0012%	
<i>Lockdown: Least deprived 20% (Quintile 5)</i>	0.0010%	-0.0008%	0.0028%		0.0019%	0.0004%	0.0033%	*
<i>Lockdown: Quintile 4</i>	-0.0003%	-0.0021%	0.0015%		-0.0009%	-0.0023%	0.0006%	
<i>Lockdown: Quintile 2</i>	-0.0022%	-0.0040%	-0.0004%	*	-0.0025%	-0.0040%	-0.0011%	**
<i>Lockdown: Most deprived 20% (Quintile 1)</i>	-0.0065%	-0.0083%	-0.0047%	***	-0.0063%	-0.0078%	-0.0048%	***
Phase 1 Vaccination Rollout	0.0016%	-0.0005%	0.0037%		0.0012%	-0.0005%	0.0030%	
<i>Phase 1: Least deprived 20% (Quintile 5)</i>	-0.0002%	-0.0032%	0.0028%		-0.0011%	-0.0035%	0.0014%	
<i>Phase 1: Quintile 4</i>	-0.0001%	-0.0031%	0.0029%		0.0002%	-0.0023%	0.0026%	
<i>Phase 1: Quintile 2</i>	-0.0004%	-0.0035%	0.0026%		-0.0010%	-0.0034%	0.0015%	
<i>Phase 1: Most deprived 20% (Quintile 1)</i>	0.0002%	-0.0028%	0.0032%		-0.0001%	-0.0026%	0.0024%	
Phase 2 Vaccination Rollout	-0.0013%	-0.0032%	0.0006%		-0.0013%	-0.0028%	0.0002%	
<i>Phase 2: Least deprived 20% (Quintile 5)</i>	0.0008%	-0.0019%	0.0034%		0.0003%	-0.0019%	0.0024%	
<i>Phase 2: Quintile 4</i>	0.0002%	-0.0025%	0.0028%		0.0001%	-0.0020%	0.0023%	
<i>Phase 2: Quintile 2</i>	0.0009%	-0.0017%	0.0036%		0.0013%	-0.0009%	0.0035%	
<i>Phase 2: Most deprived 20% (Quintile 1)</i>	0.0009%	-0.0017%	0.0036%		0.0013%	-0.0009%	0.0034%	

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Control variables: Number of vaccine-eligible children in a local authority each quarter.

Appendix 5.1 Table of a completed CORE-Q checklist.

No.	Item	Guide questions/description	Relevant page/Notes
Domain 1: Research team and reflexivity			
Personal Characteristics			
1.	Interviewer/facilitator	Which author/s conducted the interview or focus group?	Amber Sacre
2.	Credentials	What were the researcher's credentials? E.g. PhD, MD	MA in Social Science Research
3.	Occupation	What was their occupation at the time of the study?	PhD student
4.	Gender	Was the researcher male or female?	Female
5.	Experience and training	What experience or training did the researcher have?	Essex Summer School of Qualitative Data Analysis
Relationship with participants			
6.	Relationship established	Was a relationship established prior to study commencement?	163/164
7.	Participant knowledge of the interviewer	What did the participants know about the researcher? E.g., personal goals, reasons for doing the research	PhD details
8.	Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? E.g., bias, assumptions, reasons and interests in the research topic	92
Domain 2: Study design			
Theoretical framework			
9.	Methodological orientation and theory	What methodological orientation was stated to underpin the study? E.g., grounded theory, discourse analysis, ethnography, phenomenology, content analysis	86-91
Participant selection			
10.	Sampling	How were participants selected? E.g., purposive, convenience, consecutive, snowball	163/164
11.	Method of approach	How were participants approached? E.g., face-to-face, telephone, mail, email	163/164
12.	Sample size	How many participants were in the study?	164/165
13.	Non-participation	How many people refused to participate or dropped out? Reasons?	171

Setting			
14.	Setting of data collection	Where was the data collected? E.g., home, clinic, workplace	159/160
15.	Presence of non-participants	Was anyone else present besides the participants and researchers?	No
16.	Description of sample	What are the important characteristics of the sample? E.g., demographic data, date	173
Data collection			
17.	Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	167-169
18.	Repeat interviews	Were repeat interviews carried out? If yes, how many?	172
19.	Audio/visual recording	Did the research use audio or visual recording to collect the data?	159-160
20.	Field notes	Were field notes made during and/or after the interview or focus group?	No
21.	Duration	What was the duration of the interviews or focus group?	172
22.	Data saturation	Was data saturation discussed?	172
23.	Transcripts returned	Were transcripts returned to participants for comment and/or correction?	No
Domain 3: analysis and findings			
Data analysis			
24.	Number of data coders	How many data coders coded the data?	171
25.	Description of the coding tree	Did authors provide a description of the coding tree?	175
26.	Derivation of themes	Were themes identified in advance or derived from the data?	169-171
27.	Software	What software, if applicable, was used to manage the data?	169
28.	Participant checking	Did participants provide feedback on the findings?	No
Reporting			
29.	Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? E.g., participant number	Yes
30.	Data and findings consistent	Was there consistency between the data presented to illustrate themes/findings?	Yes
31.	Clarity of major themes	Were major themes clearly presented in the findings?	N/A

32.	Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	N/A
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Appendix 5.2 Participant information sheet.

Immunisation at the Deep End: The challenges of delivering the childhood vaccination programme in socioeconomically deprived areas of the North East.

Participant Information

You have been asked to participate in an interview study exploring the challenges of delivering the 0-5 childhood immunisation programme in areas of high deprivation in the North East, and evaluating the implementation of an intervention aimed at increasing uptake. This information sheet aims to provide you with a broad overview of the study and what participation would entail, in order to make an informed decision about your potential participation. If you have read the entire contents of this participant information sheet and are still interested in the study but require more information, please contact the primary researcher, Amber Sacre, using the contact details provided at the end.

What is the purpose of the study?

The main aim of the study is to explore the challenges of delivering the childhood immunisation programme faced by service providers in socioeconomically deprived areas of the North East of England, and, where possible, identify any potential solutions to these issues.

It will also evaluate the views, experiences and implementation of an intervention organised by the North East and North Cumbria (NENC) Deep End network. The intervention aims to increase the uptake of childhood immunisation by addressing some of the challenges that disproportionately affect GP surgeries in these areas.

The research study is being undertaken as part of a PhD in Population Health Sciences, based at Newcastle University. The research is funded, via scholarship, by the National Institute for Health and Care Research (NIHR) Applied Research Collaboration (ARC) Newcastle and North Cumbria (NENC).

Why have I been asked to participate?

You have been asked to participate in this study because you are one of the following:

- You work in a GP surgery that is a member of the NENC Deep End network, has registered interest in the intervention aimed at increasing vaccination uptake for children, and are involved in the 0-5 childhood immunisation programme directly.
- You work in the wider health and care system in the region and are involved in an aspect of planning, organising, delivery and/or monitoring of the 0-5 childhood immunisation programme in the region.
- You are one of the health and care workers delivering the 0-5 childhood Deep End immunisation intervention pilot described above or have had a role in the pilot development and implementation.

If you are unsure whether you are eligible, please contact the primary researcher (details provided below).

What do I have to do?

If you do not want to take part, then you do not need to do anything.

If you decide to participate, you will be asked to sign a consent form to ensure you have been provided with all the information before participating. However, you are free to withdraw from participation at any point without repercussions.

The interview will last approximately 1 hour. These interviews will be conducted via the video calling software, Zoom, where they will be audio and video recorded. A series of open-ended questions will be asked to explore the study aims.

Will my taking part in this study be kept confidential?

After the interview has been conducted, the recording will be typed up and any information that could identify you or other people will be removed. The data will then be used anonymously in the project's analysis. Due to the anonymisation process should you withdraw after the study has started, it will not be possible to remove your data.

What will happen with my data, where will it be stored?

No-one other than the research team will be able to listen to the recording or read the interview transcript. The recording and the interview transcript will be securely stored electronically on Newcastle University's network with restricted password access. The recording will be deleted one year after the end of the study and the interview transcript and consent form will be kept for maximum of seven years and then destroyed. Direct quotes from what you said may be used in the writing up of the study's findings, but these quotes will be anonymised which means no-one will be able to identify you from what you have said.

What benefit will my participation have?

You would be helping to enhance the understanding of the impact of socioeconomic deprivation on vaccination uptake in the local area. Your input will help inform decisions about future development of the intervention, future allied interventions and further related research both locally and in other parts of the country. All participants will be able to request a summary of the findings.

Does this study have ethical approval?

Yes, this study does have ethical approval from the Faculty of Medical Sciences Ethical Review Committee at Newcastle University, granted on the 04/05/2023 (Ref: 31864/2023).

Who do I contact if I have any queries or concerns, or need more information?

If you would like to speak to someone about the study or if you need any further information, please contact the primary researcher, Amber Sacre (Population Health Sciences Institute, Newcastle University) via email a.sacre2@newcastle.ac.uk. Alternatively, you can contact Dr Sarah Sowden via email sarah.sowden@newcastle.ac.uk.

Thank you for taking time to read this information.

Appendix 5.3 Participant consent form.

Immunisation at the Deep End: The challenges of delivering the childhood vaccination programme in socioeconomically deprived areas of the North East of England.

Participant Consent Form

Name of Principal Investigator: Amber Sacre (a.sacre2@newcastle.ac.uk)

	Participant Identification Number:				
					Initials
1	I confirm that I have read and understand the participant information sheet for the above study. I have had the opportunity to ask questions and received satisfactory answers.				
2	I understand that my participation is voluntary; I can choose not to answer a question and I can stop the interview at any time without giving a reason.				
3	I agree to the interview being audio/video recorded.				
4	I understand that anything I say will be treated with confidence and any documentation relating to the research will not identify me or anyone else by name.				
5	I understand that any information collected will be kept in a secure way and that some identifiable data (this consent form) will be held by the research team at Newcastle University for seven years.				
6	I understand that the information collected, following anonymisation, may be used in reports, research briefs/blogs, academic papers, contributions to books and presentations. This may include direct anonymised quotes. I give permission for the researchers to use the data in this way.				
7	I understand that information collected will be managed by the research team only and that anonymised transcribed interview data will be destroyed after a maximum period of seven years.				
8	I agree to take part in the research project.				

Consent

Name of Participant

Date

Signature or verbal consent recorded

For use by the primary researcher:

Name of Person Taking Consent

Date

Signature

Contact persons: If you have any questions about this research, please email:

Amber Sacre: a.sacre2@newcastle.ac.uk

Dr Sarah Sowden: sarah.sowden@newcastle.ac.uk

Newcastle University is responsible for providing information about how personal data is used under the Data Protection Act 2018 and General Data Protection Regulation. For its general policy, see:

<https://www.ncl.ac.uk/data.protection/accessyourpersonaldata/>

Appendix 5.4 Newcastle University Research ethical approval decision tool results.

University Ethics Form Version 3

Applicant Details (922)

Is this approval for a: (11240)

Type: (!/list-dropdown)

A2 - Student Project

What type of degree programme is being studied? (11319)

Type: (!/list-dropdown)

A3 - Postgraduate Research (e.g. PhD)

Name of Principal Researcher (11241)

Type: (S/text-short)

Amber Sacre

Please enter your email address (11258)

Type: (S/text-short)

a.sacre2@ncl.ac.uk

Please select your school/academic unit (11242)

Type: (!/list-dropdown)

A27 - Population Health Sciences

Please enter the module code (11243)

Type: (S/text-short)

Please enter your supervisor's email (11259)

Type: (S/text-short)

adam.todd@ncl.ac.uk

Please select your supervisor's school/unit: (11244)

Type: (!/list-dropdown)

A20 - School of Biomedical Sciences/ School of Pharmacy Project Details (923)

Project Title (11245)

Type: (S/text-short)

Unequal vaccines? A mixed methods study exploring socioeconomic inequalities in the North East.

Project Synopsis (11257)

Type: (T/text-long)

The project explores inequalities in vaccination uptake, and whether these differences can partly be explained by socioeconomic status. It consists of three empirical elements: an umbrella systematic review exploring the existing literature; interviews with healthcare professionals (admin staff, general practitioners and nurses) and local government individuals involved in

delivering, or organising, the childhood immunisation programme in the North East; a statistical analysis of vaccine uptake data from the UK, combined with local authority identifiers, to quantitatively contextualise the North East. The interviews will be used to collect information on the challenges faced when delivering the immunisation programme in socioeconomically deprived areas. They will also explore attitudes towards a childhood immunisation intervention that is being implemented locally, informed by the Deep End NENC team, and is aimed at increasing uptake. The primary researcher (Amber Sacre) is also a member of the Deep End NENC team.

Project start date (11260)

Type: (D/date)

15/05/2023

Project end date (11261)

Type: (D/date)

31/10/2023

Is the project externally funded? (11262)

Type: (!/list-dropdown)

A2 - Yes - I do not have a NUProjects/MyProjects reference number

Project Funder Details (11264)

Type: (;/array-multi-flexi-text)

	Funder name - SQ001	Reference - SQ002	Value to Newcastle - SQ003
Primary funder – SQ001	NIHR ARC NENC	NIHR200173	
Secondary Funder – SQ002			
Tertiary Funder – SQ003			

Does your project involve collaborators outside of the University? (11265)

Type: (Y/yes-no)

Yes

Please provide a list of the collaborating organisations. (11266)

Type: (T/text-long)

The North East and North Cumbria (NENC) Deep End network, which is funded by the NENC Integrated Care System (<https://deependnenc.org/>).

Existing Ethics, Sponsorship & Responsibility (930)

Has ethical approval to cover this proposal already been obtained? (11267)

Type: (Y/yes-no)

No [X]

Will anyone be acting as sponsor under the NHS Research Governance Framework for Health and Social Care? (11270)

Type: (Y/yes-no)

No [X]

Do you have a Newcastle upon Tyne Hospitals (NUTH) reference? (11272)

Type: (Y/yes-no)

No [X]

Will someone other than you (the principal investigator) or your supervisor (for student projects) be responsible for the conduct, management and design of the research? (11274)

Type: (Y/yes-no)

No [X]

Animals (I) (924)

The [Animals \(Scientific Procedures\) Act](#) defines protected animals as: 'any living vertebrate other than man...in its foetal, larval or embryonic form.....from the stage of its development when:

- (a) in the case of a mammal, bird or reptile, half the gestation or incubation period for therelevant species has elapsed; and
- (b) in any other case, it becomes capable of independent feeding'.

In practice 'Protected' animals are all living vertebrates (other than man), including some immature forms, and cephalopods (e.g. octopus, squid, cuttlefish).

Using this definition, does your research involve the observation, capture or manipulation of animals or their tissues? (11246)

Type: (Y/yes-no)

No [X]

NHS, Health & Social Care: Facilities, Staff & Patients (I) (925)

Will the study involve participants recruited by virtue of being NHS patients or service users, their dependents, their carers or human tissues or the use of NHS & Health/Social Care

Facilities or otherwise require REC approval? (11247)

Type: (Y/yes-no)

No [X]

Human Participants in a Non-Clinical Setting (I) (926)

Does the research involve human participants e.g. use of questionnaires, focus groups, observation, surveys or lab-based studies involving human participants? (11249)

Type: (Y/yes-no)

Yes

Does the study involve any of the following? (11250)

Type: (M/multiple-opt)

- a. The study involves children or other vulnerable groups; including those who are relatively or absolutely incapable of protecting their own interests, or those in

unequal relationships e.g. participants who are subordinate to the researcher(s) in a context outside the research? (11356)

- b. The study requires the co-operation of a [gatekeeper](#) defined as someone who can exert undue influence) for initial access to the groups or individuals to be recruited e.g. students at school, members of a self-help group, or residents of a nursing home? NB. The IoN & School of Psychology volunteer pools are not considered gatekeepers
- c. It is necessary for participants to take part in the study without their knowledge and consent e.g. covert observation of people in non-public places?. (11358)
- d. Deliberately misleading participants in any way? (11359)
- e. Discussion of sensitive topics e.g. sexual activity or drug use?* (11360)
- f. The administration of drugs, placebos or other substances (e.g. food substances, vitamins) to the study participants. (11361)
- g. Invasive, intrusive or potentially harmful procedures of any kind?* (11362)
- h. Obtaining blood or tissue samples?* (11363)
- i. Pain or more than mild discomfort? (11364)
- j. Psychological stress, anxiety, harm or negative consequences beyond that encountered in normal life? (11365)
- k. Prolonged or repetitive testing i.e. more than 4 hours commitment or attendance on more than two occasions? (11366)
- l. Financial inducements (other than reasonable expenses and compensation for time)? (11379)

Data (I) (927)

Does the research involve the viewing, usage or transfer of sensitive data or personal data as defined by the [General Data Protection Regulation \(GDPR\)](#) or data governed by statute such as the [Official Secrets Act 1989](#) / [Terrorism Act 2006](#), commercial contract or by convention e.g. client confidentiality? (If you are unsure please tick YES and complete the sub-questions) (11251)

Type: (Y/yes-no)

No [X]

Environment (I) (928)

Will the study cause direct or indirect damage to the environment or emissions outside permissible levels or be conducted in an [Area of Special Scientific Interest](#) or which is of cultural significance? (11253)

Type: (Y/yes-no)

No [X]

International Projects (I) (929)

Will the research be conducted outside of the UK or [European Economic Area \(EEA\)](#), or will it involve international collaborators outside the EEA? (11255)

Type: (Y/yes-no)

No [X]

Next Steps (931)

Based on your responses your project has been categorised as (ethically) low risk and no further review is required before you start work. You will receive a formal approval

email on submission of this form. Should your project change you may need to apply for new ethical approval. (11282)

Type: (X/boilerplate)

Supporting Documentation (940)

Please upload any documents (not uploaded elsewhere in the application) which you think are relevant to the consideration of your application. (11308)

Type: (/upload-files)

Summary and Submission (941)

Thank you for completing the University's Ethical Review Form. Based on your answers the University is satisfied that your project has met its ethical expectations and grants its ethical approval.

Please be aware that if you make any significant changes to your project then you should complete this form again as further review may be required. Confirmation of this decision will be emailed to you.

Please complete the declaration to submit your application.

Declaration

I certify that: (11314)

Type: (M/multiple-opt)

☒ [X]

the information contained within this application is accurate. (11441)

☒ [X]

the research will be undertaken in line with all appropriate, University, legal and local standards and regulations. (11442)

☒ [X]

I have attempted to identify the risks that may arise in conducting this research and acknowledge my obligation to (and rights of) any participants. (11443)

☒ [X]

no work will begin until all appropriate permissions are in place. (11444)

Appendix 5.5 NHS HRA ethical approval decision tool results.



Medical
Research
Council



Do I need NHS REC review?

 **To print your result with title and IRAS Project ID please enter your details below:**

Title of your research:

Immunisation at the Deep End: The role of socioeconomic inequalities in vaccination uptake.

IRAS Project ID (if available):

Your answers to the following questions indicate that **you do not need NHS REC review for sites in England.**

This tool only considers whether NHS REC review is required, it does not consider whether other approvals are needed. You should check what other approvals are required for your research.

You have answered **'YES'** to: Is your study research?

You answered **'NO'** to all of these questions:

Question Set 1

- Is your study a clinical trial of an investigational medicinal product?
- Is your study one or more of the following: A non-CE marked medical device, or a device which has been modified or is being used outside of its CE mark intended purpose, and the study is conducted by or with the support of the manufacturer or another commercial company (including university spin-out company) to provide data for CE marking purposes?
- Does your study involve exposure to any ionising radiation?
- Does your study involve the processing of disclosable protected information on the Register of the Human Fertilisation and Embryology Authority by researchers, without consent?

Question Set 2

- Will your study involve potential research participants identified in the context of, or in connection with, their past or present use of services (NHS and adult social care), including participants recruited through these services as healthy controls?
- Will your research involve prospective collection of tissue (i.e. any material consisting of or including human cells)

from any past or present users of these services (NHS and adult social care)?

- Will your research involve prospective collection of information from any past or present users of these services (NHS and adult social care)?
- Will your research involve the use of previously collected tissue and/or information from which individual past or present users of these services (NHS and adult social care), are likely to be identified by the researchers either directly from that tissue or information, or from its combination with other tissue or information likely to come into their possession?
- Will your research involve potential research participants identified because of their status as relatives or carers of past or present users of these services (NHS and adult social care)?

Question Set 3

- Will your research involve the storage of relevant material from the living or the deceased on premises in England, Wales or Northern Ireland without a storage licence from the Human Tissue Authority (HTA)?
- Will your research involve storage or use of relevant material from the living, collected on or after 1st September 2006, and the research is not within the terms of consent for research from the donors?
- Will your research involve the analysis of human DNA in cellular material (relevant material), collected on or after 1st September 2006, and this analysis is not within the terms of consent for research from the donor? And/or: Will your research involve the analysis of human DNA from materials that do not contain cells (for example: serum or processed bodily fluids such as plasma and semen) and this analysis is not within the terms of consent for research from the donor?

Question Set 4

- Will your research involve at any stage procedures (including use of identifiable tissue samples or personal information) involving adults who lack capacity to consent for themselves, including participants retained in study following the loss of capacity?
- Is your research health-related and involving offenders?
- Does your research involve xenotransplantation?
- Is your research a social care project funded by the Department of Health and Social Care (England)?
- Will the research involve processing confidential information of patients or service users outside of the care team without consent? And/ or: Does your research have Section 251 Support or will you be making an application to the Confidentiality Advisory Committee (CAG) for Section 251 Support?

If your research extends beyond **England** find out if you need NHS REC review by selecting the 'OTHER UK COUNTRIES' button below.

OTHER UK COUNTRIES

If, after visiting all relevant UK countries, this decision tool suggests that you do not require NHS REC review [follow this link for final](#)

confirmation and further information.

Print This Page

NOTE: If using Internet Explorer please use browser print function.

**About this tool Feedback Contact Glossary Algorithm
Accessibility**

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