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First and formost I dedicate this thesis to my ‘little nan’ who sadly is no longer here to see me complete the work.

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1. INTRODUCTION

Background

Overweight and obesity are defined as "abnormal or excessive fat accumulation that presents a risk to health" (World Health Organization, 2005). The worldwide increase in the prevalence of obesity is well documented. In the UK, research carried out by the Government Office for Science reported that 5% of 11 to 15 year old boys and 11% girls in that age range are currently obese. If no action is taken, it is predicted that 55% of boys and 70% of girls (under 20 years) could be overweight or obese by the year 2050 (Butland *et al.* 2007). The health risks associated with overweight and obesity are similarly well documented; being overweight or obese is associated with a higher likelihood of suffering numerous chronic illnesses, including cardiovascular disease, cancer and Type 2 diabetes (World Health Organization 2003a, 2005).

While genetic make up may be important in determining a person's susceptibility to weight gain, an individual's energy balance is determined by energy intake and energy expenditure. Diet and lifestyle factors are the primary reason for the high rates of excessive body fat (Willet, 1998). The key causes of the global increase in overweight and obesity have been identified as increased consumption of energy-dense foods high in fats and sugars, increased sedentary behaviour and reduced physical activity (Butland *et al.* 2007).

Longitudinal studies are important in understanding when, how and why changes occur over time. Adolescence (defined here as age 11 years to age 18 years) in particular is an important period in the life cycle as this is a period of rapid growth and development, physically, socially and psychologically, during which significant changes occur. At age 16-18 years young people are in the transition from adolescence to young adulthood and, in addition to academic demands or the challenges of entering the workforce, young people tend to have busy personal and social lives.

Studies have reported that eating habits formed in adolescence (11-12 years) can continue into adulthood (Birch, 1987; Lake *et al.* 2004a) and may have long-term health implications. For example, being overweight or obese as an adolescent is associated with being overweight or obese as an adult (Craigie *et al.* 2003). However, longitudinal studies of diet and adiposity in adolescents are scarce. In 2000, the third in a series of cross-sectional studies of 11-12 year olds in Northumberland was carried out. This study investigated dietary change across three decades (1980, 1990 and 2000). This thesis reports on a longitudinal study of the 2000 cohort followed up when they were aged 16-18 years.

The purpose of this study was to test the hypothesis that diet and adiposity track from early to late adolescence.

Aims and objectives

The aims of the project were to:

1. To describe adiposity and lifestyle characteristics (dietary intake, physical activity, smoking behaviour) of these young people at age 16-18 years;
2. To identify changes in, and tracking of, energy intake and macronutrient contribution to energy of these participants between ages 11-12 years and 16-18 years;
3. To identify changes in, and tracking of, adiposity from 11-12 years to 16-18 years and further
4. To determine factors predicting adiposity at age 16-18 years.

To achieve these aims, the objectives of this study were to measure diet, other health related behaviours (notably smoking and physical activity) and adiposity at 16-18 years. Two three-day food diaries, completed at six month intervals, were used to measure dietary intake at both early and late adolescence (age 11-12 and 16-18 years). A questionnaire (at 16-18 years) was used to identify health related behaviours. Height and weight were measured at age 11-12 years. At 16-18 years, height, weight, waist and hip circumference and body composition were measured. In addition, physical activity was measured using Accelerometer™ activity monitors. Of the original 2000 cohort, 46 % (n=193) were followed up at age 16-18 years.

Organisation of this thesis

Following a review of the relevant literature (Chapter 2), Chapter 3 describes the approach and methods used to search for and to recruit, the young people who had been participants in the original study at age 11-12 years (Fletcher, 2003). Chapter 3 also provides details of the methods used in the assessment of dietary intake, the measurement of physical activity and lifestyle and the collection of anthropometric data of the young people at age 16-18 years.

Chapter 4 describes the study participants at age 16-18 years in terms of their education/employment, place of residence and living arrangements. In addition, Chapter 4 details demographic characteristics, anthropometric measurements and health related behaviours. This chapter concludes with discussion of associations between nutrient intake and adiposity, between physical activity and adiposity, and between nutrient intake and physical activity in these young people at age 16-18 years.

To identify how representative the data of the present study were of the original study sample in 2000, in Chapter 5 the characteristics (gender, social class, anthropometric measurement and dietary intake) of respondents (follow-up participants and non-participants) at age 11-12 years were compared with the whole 2000 sample. In addition, to determine how representative this study sample was of the UK national population of the same age, characteristics of this follow-up study sample (at age 16-18 years) were compared with data from the most recent UK study of young people i.e. the National Diet and Nutrition Survey (NDNS) of 4-18 year olds (Gregory, Lowe *et al.* 2000).

Because being overweight as an adolescent is associated with being overweight as an adult (Lake *et al.* 1997; Craigie *et al.* 2003) and because eating habits formed in adolescence continue into adulthood (Lake *et al.* 2004b), it is likely that poor dietary habits in adolescence will have important implications for health and well-being in adulthood (for example (Neumark-Sztainer *et al.* 1999). For this reason, there is interest in the tracking of health-related behaviours and of adiposity. Chapter 6 compares the height, weight and BMI of study participants at age 16-18 years with those of the same individuals at age 11-12 years and provides estimates of changes in, and tracking of, anthropometric measurements (focussed on overweight and obesity) between age 11-12 and 16-18 years. Similarly Chapter 7 compares the dietary intake from age 16-18 years with that of these young people at age 11-12 years and provides estimates of changes in, and tracking of, diet over this period of adolescence.

Chapter 8 concludes the thesis with an analysis of factors which, in combination, predict anthropometric outcomes at age 16-18 years. In each of the Results chapters (Chapters 4-8), the findings of the present project are set in the context of what is already known and areas requiring further research are identified.

The main focus of the thesis is energy balance. Therefore reporting of dietary data has been limited to Energy Intake (EI; which is expressed as both MJ/d and MJ/kg body mass/d) and macronutrient contribution to Energy Intake (%EI: expressed as both g/d and g/kg body mass/d).

2. REVIEW OF THE LITERATURE

Chapter overview

Introduction

Overweight and obesity are defined as "abnormal or excessive fat accumulation that presents a risk to health" (World Health Organization, 2003b). The worldwide increase in the prevalence of obesity is well documented. In the UK, research carried out by the Government Office for Science reported that 5% of 11 to 15 year old boys and 11% girls in that age range are currently obese (McPherson *et al*. 2007). If no action is taken, it is predicted that 55% of boys and 70% of girls (under 20 years) could be overweight or obese by the year 2050 (McPherson *et al*. 2007).

The health risks associated with overweight and obesity are similarly well documented; being overweight or obese is associated with a higher likelihood of suffering numerous chronic illnesses, including, among others, cardiovascular disease and cancer and Type 2 diabetes (World Health Organization, 2003a, 2005; Kopelman, 2007).

While genetic make up may be important in determining a person's susceptibility to weight gain, an individual's energy balance is determined by energy intake and energy expenditure (Hill, 2006). The key causes of the global increase in overweight and obesity are cited as diet and lifestyle factors, such as increased consumption of energy-dense foods, high in fat, low in fibre and sugar-rich drinks, increased sedentary behaviour and reduced physical activity (Jebb, 2007).

Adolescence (defined here as age 11 years to age 18 years) in particular is an important period in the life cycle as this is a period of rapid growth and development physically, socially and psychologically, during which significant changes occur (Webb, 2002). At age 16-18 years young people are in the transition from adolescence to young adulthood and in addition to academic demands or the challenges of entering the workforce young people tend to have busy personal and social lives (Wills, 2005). Furthermore studies have reported that eating habits formed in adolescence (11-12 years) can continue into adulthood (Birch, 1999; Lake *et al.* 2004b) and may have long-term health implications; for example, being overweight or obese as an adolescent is associated with being overweight or obese as an adult (Lean, 2000; Guo *et al.* 2002; Craigie *et al.* 2003).

With the notion that diet and lifestyle in adolescent years are generally unhealthy (Wills, 2005) and that poor diet and excess weight in childhood continues into adulthood (Lake *et al.* 2004b), the aims of this chapter are:

1. To describe the demographic and lifestyle characteristics of adolescents (aged 11 to 18 years) that might explain the energy intake and adiposity in the young people of this study at age 16-18 years (Chapter 2.1 and Chapter 2.3);
2. To describe methods available for assessing adiposity from a public health perspective (Chapter 2.2);
3. To discuss dietary studies of adolescents with which to compare the findings of this study population (Chapter 2.3);
4. To describe the various methods available for dietary assessment in epidemiological studies (Chapter 2.4);
5. To explain the method by which behaviour (e.g. dietary intake) in childhood can be tracked into adulthood (Chapter 2.5); and
6. To discuss methods by which physical activity can be measured in adolescents (Chapter 2.6)

2.1. Adolescence

Adolescence is an intensely anabolic period and a time when there is inevitably a relatively high demand for energy and nutrients to sustain rapid growth (Webb, 2002). It is a time of vulnerability and growing independence, including increased opportunities to make decisions about what and when to eat (Barasi, 2003). A process of transition towards greater autonomy from parents begins (Noller & Callan, 1991) and peers become increasingly central to many areas of the adolescent's life (Shepherd & Dennison, 1996). Adolescents spend more time away from home as a result of social, school, and community activities and jobs. Subsequently, increasingly busier lifestyle is among the most important factors influencing adolescent food choice i.e. the amount of time an adolescent "*has or wants to spend on food*" (Neumark-Sztainer *et al.* 1999).

In addition, adolescence is a time of increased awareness of the body, its shape and size, most especially for females (Davis & Furnham, 1986). Thinness is seen as the desirable body shape for women in Western cultures and, thus, many adolescent females, and increasing numbers of adolescent males, strive to achieve this goal by means of dietary restraint (Shepherd & Dennison, 1996). Adolescent lifestyles, influenced by the desire to fit social norms, may not be conducive to encourage teenagers to eat in a manner that meets the increased and changing nutrition needs during this period (Neumark-Sztainer *et al.* 1999). Lack of sense of urgency regarding future health may make nutrition a low concern among adolescents.

Poor eating patterns may result in nutritional problems that can impair adolescent growth and development (Society for Adolescent Medicine, 1999). Nutritional intake during this period may have long-term health implications. For example, being overweight as an adolescent is associated with being overweight as an adult (Lean, 2000; Guo *et al.* 2002; Craigie *et al.* 2004). Furthermore eating habits formed in adolescence continue into adulthood (Lake *et al.* 2004a) consequently poor dietary habits among youth have important implications for health and well-being in adulthood (for example (Neumark-Sztainer *et al.* 1999).

Physical inactivity is linked with an increase in obesity (Katzmarzyk *et al.* 2001) among adolescents (Nader *et al.* 2008). There is concern that low levels of physical activity may predispose children to the development of obesity and chronic disease later in life (Goran *et al.* 1999; Boreham *et al.* 2004), however there is considerable disagreement as to the timing and magnitude of these trends (Sallis *et al.* 1993).

2.2. Adiposity

2.2.1. Anthropometric measurement methods

A number of methods are available for assessing adiposity, such as dual X-ray absorptiometry (DEXA), underwater weighting and isotope dilution, but can be complex, time consuming and expensive (McCarthy *et al*. 2006). Body mass index (BMI) defined as the weight in kilograms divided by the square of the height in metres (kg/m^2) is a widely accepted method of classification of overweight and obesity in adults (World Health Organization, 1995).

The use of BMI for classification of adiposity in children and young people however, has been subject to more debate than for adults. "*Between the ages of 12 and 17 years boys gain an average 26cm in height and 26 kg in weight; girls gain 23 cm in height and 21kg in weight between the ages of 10 and 15 years*" (Webb, 2002). During adolescence there is the added complication that not only height and weight, but also body composition is still changing (Friedman, 1997; Page and Fox, 1998). To account for the difference in timing of the growth spurts of height and weight, and the systematic physiological differences between males and females, the International Obesity Task Force (IOTF) developed age and gender specific BMI cut-offs which are predictive of BMI of >25 (overweight) and >29.9 (obese) in adulthood (Cole *et al.* 2000).

However, although BMI is relatively simple to calculate and has been a valuable tool in monitoring trends in obesity, the assessment of adiposity by BMI is a proxy measure and does not distinguish between fat, lean tissue or bone (Lean, 2000; McCarthy *et al.* 2006). For example, males gain proportionately more muscle and lean tissue than fat and females gain more fat than muscle as part of their natural sexual and reproductive physiology (McCarthy *et al.* 2006). Subsequently, measures of BMI can lead to significant misclassification in some highly muscular individuals with low body fat and a high BMI (McCarthy *et al.* 2006).

Research investigating the health risks associated with excess body fat in children and adolescents has studied up to a maximum age of 16 years (McCarthy *et al.* 2006) (the usual upper age limit for childhood) and such data based on 16-18 year olds are scarce. The health risks of excess body fat for adults have traditionally been associated with inappropriate weights for height expressed as BMI (Garrow, 1981) with high BMI (>25 in adults) being associated with increased risk of morbidity and mortality (Kopelman, 2007). However as stated previously BMI does not indicate the level of central adiposity associated with cardiovascular disease risk factors including dyslipidemia, hypertension, and insulin resistance (Katzmarzyk *et al.* 2001). For example in a clinical setting some normal weight individuals display the expected chronic complications of obesity such as diabetes or cardiovascular disease, whereas some obese patients could be characterised by a fairly normal metabolic risk factor profile (Despres, 2001).

Considerable research has gone into developing bio-impedance monitors that can distinguish between lean and fat tissue on the basis of their differential conductance and impedance characteristics (McCarthy *et al,* 2006). Bio-impedance analysis (BIA) offers additional body composition (lean and fat mass) information to routine anthropometry. BIA is based on the theoretical relationship between the volume of a conductor and its impedance. When applied to the human body it assumes that the fat-free mass (FFM) contains virtually all the body's conducting electrolytes. The impedance value is combined with anthropometric data into a prediction equation to give compartment measures (Tyrrell *et al*. 2001). Early BIA method required careful placement of electrodes on the arm and leg. Measurement using foot to foot BIA is quick and simpler in that the subject is only required to stand on the plate surface which contains pad electrodes. Foot to foot BIA is comparable to conventional (arm and leg) BIA in adults (Nunez *et al.* 1997) and in children (Tyrrell *et al.* 2001). Nevertheless whilst BIA was found to be a useful tool, its accuracy depends on the use of an appropriate equation and should be considered in the validation of BIA. In a similar way to Cole *et al.* (2000), McCarthy *et al.* (2006) produced age and sex specific reference curves for use in children and adolescents which also define overfat and obese individuals. It is important to note that these have only been validated in Caucasian children and on a specific bio-impedance monitor.

It is now well established that it is not only the amount of body fat that is important for reducing the risk to health, but where in the body it is distributed. Several of the metabolic consequences of obesity, such as Type 2 diabetes, hypertension and hyperlipidemia relate specifically to the accumulation of intra-abdominal fat (Kopelman, 2007). Consequently, a central distribution of body fat is now considered a stronger cardiovascular risk factor than elevated BMI (Lean, 2000; McCarthy *et al.* 2003). Whilst several anthropometric methods of estimating body fat distribution are available, the waist to hip ratio (WHR) and waist circumference (WC) alone offer alternatives to BIA as simple measures of body composition, or at least of body fat distribution. Relative fat distribution can be estimated by the ratio of waist circumference to hip circumference (WHR). Although previously useful for risk *assessment*, WHR is difficult to interpret biologically, reflecting not only fat distribution but also muscle distribution

(Molarius and Siedell, 1998). Also because both waist circumference and hip circumference can change simultaneously with weight reduction, the ratio of WHR changes very little. Further, WHR as a ratio is an index of the relative amount of abdominal fat, therefore both non-obese and obese individuals could have the same elevated WHR. Therefore in a public health context, WHR is not helpful for risk *management* (Ashwell *et al.* 2005) and WC which is a simple and inexpensive anthropometric tool has been proposed as a preferable measure of visceral adipose tissue in both adults (Taylor *et al*. 2000; Harris *et al.* 2000; Despres, 2001) and children (Freedman *et al.* 1999; Garnett *et al.* 2007).

The WC alone is sometimes favoured due to its simplicity, easier biological interpretation, and because it has been shown to be a better indicator of visceral fat and total fatness than the WHR (Lean *et al.* 1996; Han *et al.* 1997 Molarius & Seidell, 1998). McCarthy and colleagues (2001) have developed WC percentile curves for use in children and adolescents; however these were to a maximum age of 16.9 years. The World Health Organization has based recommendations for identifying health risks associated with central distribution of body fat (non-Asians) on cut-offs by Lean *et al.* (1995). By natural physiological development males have larger waist circumferences (Ashwell *et al.* 1997), thus a WC ≥94cm for males and ≥80cm for females indicates an increased health risk and WC >102cm for males, and >88cm for females indicates a high health risk (Lean *et al.*1995).

2.2.2. Aetiology and prevalence of obesity

Obesity has come to be considered a global epidemic and excess body weight is now the most common childhood disorder in Europe (World Health Organization, 2003a). There has been an increase in the prevalence of overweight and obesity in British children over recent years. In a UK government report ‘Foresight: Tackling Obesities: Future Choices’ (Butland *et al*. 2007), raw data from ‘The Health Survey for England 2004’ were used to identify current trends in the UK (McPherson *et al.* 2007). These data identified a 21% prevalence of overweight and obesity for adolescents aged 13 to 16 (McPherson *et al*. 2007). In the 16 to 24 year old age range, 23 per cent of men and 19 per cent of women were overweight, and a further 6 per cent of men and 8 per cent of women were obese (McPherson *et al*. 2007). Moreover trends in waist circumference of 11-16 year olds have greatly exceeded those in BMI (McCarthy *et al.* 2003).

The aetiology of overweight and obesity is complex and multifaceted (Butland *et al.* 2007). The global increase in overweight and obesity are cited as diet and sedentary lifestyles; however research is divided on the primary causal factor (Jebb, 2007). While much emphasis is placed on dietary content, there is evidence that the British are becoming more overweight in spite of consuming less energy than in the 1970's (Prentice & Jebb, 1995, Hill, 2006).

Research highlighted in the UK government report 'Foresight: Tackling Obesities: Future Choices' illustrates the complexities of determining any single cause of obesity (Butland *et al*. 2007). There are biological factors that maintain homeostatic balance, for example a number of studies in humans have identified a number of specific genes associated with obesity. Foetal and infant growth is also cited as one determinant of future risk of obesity (Barker in Butland *et al*. 2007). Eating and physical activity behaviours, environments, people's beliefs and attitudes and broader economic and social drivers all have a role to play in determining obesity (Butland *et al.* 2007).

Other plausible contributory factors of obesity in children and adolescents have been reported, for example differences in the age of the onset of puberty for example may affect fat deposition (World Health Organization, 1995; Martinez, 2000). Post pubertal fat deposition in both females and males tends to be more central (waist and hip) rather than general (Lawlor & Chaturvedi, 2006) and may also be a critical period for the development of atherosclerosis. McGill (2000) suggested that late adolescence (i.e.

from age 15-19 years) is the key time when fatty streaks convert to raised atherosclerotic lesions (McGill, 2000). This also corresponds with the age at which BMI and skinfold thickness increase in young adults who go on to develop the metabolic syndrome (Ferreira, 2005). More recently, Baker *et al.* (2007) reported data from a cohort of Danish school children in whom higher BMI at the age of 7 to13 years in boys (age 10 to 13 years in girls) was associated with increased risk of CHD in adulthood (from the age of 25 years). Furthermore the associations became stronger with increasing age of the child.

In addition, studies have reported that overweight and obese children are more likely to become overweight or obese adults (for example, Wardle *et al*. 2006; Johannsson *et al.* 2006). Adult obesity increases the risk of suffering significant health consequences including hypertension, Type 2 diabetes and cardiovascular disease. In the shorter term, obesity and overweight can have significant impact on psychological wellbeing, with many adolescents developing negative self image and experiencing low self-esteem (Krebs *et al*. 2007).

Research into the dietary determinants of obesity in adolescents is scarce and has largely been in relation to body image and dieting (Chapter 2.3.1) or specific nutrients. For example in a US study of children, Nicklas *et al.* (2003) reported that consumption of sweets and total gram consumption of sweetened beverages and meats were positively associated with overweight status, however the variance explained by the model was very small.

As identified in the recent Foresight report, many complex dietary factors are associated with obesity such as foods with high energy density, diets high in fat and low in fibre (Butland *et al* 2007), however scientists have reached a consensus that obesity results from an imbalance in the energy balance equation (Krebs *et al.* 2007). Body fatness is a biological function of the balance of energy intake and energy expenditure (Harnack & Schmitz, 2006). If energy intake exceeds energy expenditure, the excess energy is stored as body fat regardless of its source, but excess energy from fat is stored with greater efficiency than excess energy from carbohydrate (Hill, 2006). If energy expenditure is lower than energy intake the unexpended energy is stored as adipose tissue (Harnack & Schmitz, 2006). However, there are fluctuations in energy balance as a result of day to day variations in diet and physical activity patterns (Hill, 2006). Consequently, it is suggested that the cause of the rising prevalence of obesity may be a growing imbalance between energy intake and energy expenditure attributable to an habitual increase in total energy intake and/or a downward shift in energy expenditure (Harnack & Schmitz, 2006; Hill, 2006, Jebb, 2007). Efforts to reduce obesity by psychological means centre on the two factors that are behaviourally controllable. These include a change in eating habits to reduce energy intake and adoption of exercise habits to increase energy expenditure (World Health Organization, 2003b).

The health recommendation for physical activity in adults is at least 30 minutes of moderate activity per day, and for children (<16yrs) is at least 1 hour per day (Department of Health, 2004). In recent decades however, children and adolescents have engaged in less exercise (Jebb, 2007). Importantly this decline in exercise has coincided with an increase in sedentary activities; proxy measures of physical inactivity such as car ownership, computer use and television viewing seem more closely related to changes in obesity (Prentice and Jebb, 1995; Utter *et al.* 2003).

Descriptive studies of physical activity have consistently reported that males are more active than females (Sallis, 1993; Trost, 1999; Trost *et al.* 2001, Gallagher *et al.* 2002; Ekelund *et al.* 2005) and that physical activity declines with age (Sallis, 1993; Trost, 1999). The association between physical activity and obesity however, has produced contrasting results. Sallis *et al.* (2000), Ball *et al.* (2001) and Ekelund *et al.* (2002) for example found greater activity levels to be associated with lower BMI's. Treuth *et al.*

(2005) in a US cross sectional study of males and females aged 7 to 19 years reported BMI positively associated with sedentary time; and negatively correlated with time spent in light activity but only in females. No association was found for males. Similarly, Ortega *et al.* (2007) reported Swedish children and adolescents with low levels of vigorous physical activity were more likely to be overweight.

The term obesogenic has been used to describe environments which encourage and promote high energy intake and reduced physical activity. A recent World Health Organization report concluded that the obesogenic environment appears to be largely directed at the adolescent market, making healthy choices more difficult (World Health Organization, 2005). The growing prevalence of adolescent obesity can therefore probably be attributed to a combination of physical inactivity, and energy intake more than energy expenditure (Lobstein, 2004). However this simplistic explanation does not capture the complexities of the pathways to obesity as described recently in the Foresight Report 2007 by Butland *et al.* (2007). That is "*obesity is the consequence of interplay between a wide variety of variables and determinants related to biology, eating behaviours and physical activity, set within a social, cultural and environmental landscape*" (Butland *et al*. 2007).

2.3. Adolescent food choice and obesity

Adolescent eating patterns are established through a complex process involving internal and external factors such as food preferences and availability, body weight perception, and parental and peer influences (Story & Resnick, 1986). The largest UK study to date of food consumption patterns in adolescents is the National Diet and Nutrition Survey (NDNS) of young people aged 4 – 18 years (Gregory *et al.* 2000). The NDNS is a comprehensive cross-sectional survey of approximately 2100 young people age 4 to 18 years. The survey was carried out throughout 1997 and used the weighed intake methodology for dietary assessment of the dietary habits and nutritional status of the population in Great Britain in 1997. The authors found that the foods most commonly consumed by young people in the survey were white bread, savoury snacks, chips, biscuits, potatoes and chocolate confectionery. In the week of record approximately 75% drank carbonated soft drinks with 45% consuming low calorie versions. Ten per cent of 15 to 18 year old girls reported that they were vegetarian or vegan and 16% of this age group said they were dieting to lose weight. About 58% of 15 to 18 year olds and 16% of the 11 to 14 year olds reported that they had consumed alcohol during the past week. Mean energy intakes were lower than estimated average requirements (EARs) for all age/sex groups but were the lowest in relation to the EARs for 15 to 18 year old girls. Energy intakes in this survey were lower than in a previous survey (1983) of 10 to 11 and 14 to 15 year old school children (Gregory *et al.* 2000). The average proportion of energy derived from total fat was 35% for boys and 36% for girls, close to the COMA recommendation of 35% (Department of Health, 1991). The average proportion of food energy derived from saturated fatty acids was 14.2% for boys and 14.3% for girls, above the COMA recommendation of 11% (Department of Health, 1991). Although there were some regional differences in vitamin and mineral intakes, there were few significant differences in energy and macronutrient intakes between regions (Gregory *et al.* 2000). Indicators of socio-economic status such as receipt of benefits, household income and social class showed that young people, particularly boys, in households of lower socio-economic status had lower intakes of energy, fat, some other macronutrients and most vitamins and minerals (Gregory *et al.* 2000).

Current guidelines encourage people to eat a diet low in saturated fat and choose a variety of fruits and vegetables (at least five portions per day), eat whole grains every day, and be physically active each day (Food Standards Agency, 2010). Despite the widespread dissemination of these guidelines and the importance of healthy eating in adolescence, nutritional problems are prevalent among adolescents (Wills, 2005). Many youths engage in unhealthy dieting practices and have erratic eating patterns that include high intakes of fast foods (Watt and Sheiham, 1996; Wills, 2005) and other foods high in fat and sugar, as well as low intakes of fruits, vegetables, and calcium rich foods (Neumark-Sztainer *et al.* 1999; Croll *et al.* 2001).

Much attention has focused recently on adolescents' high consumption of fast food and confectionery. Fast food typically incorporates all of the potentially harmful dietary factors including saturated and trans-fat (fat from partially hydrogenated vegetable oils), a high glycaemic index, high energy density and increasingly, large portion size. These foods also tend to be low in fibre, micronutrients and antioxidants (Ebbeling *et al.* 2002).

Adolescent consumption of carbonated soft drinks is another cause of concern. The physiological effects of energy intake on satiation appear to be different for energy in fluids as opposed to solid foods (World Health Organization, 2003a). This means that consumption of energy at mealtimes may not be adjusted to take into account the energy consumed as carbonated soft drinks, thus contributing to obesity (Ludvig *et al.* 2001). Until recently carbonated soft drinks were widely accessible to school children in the UK. In the United Kingdom more than 70% of adolescents consume carbonated drinks on a regular basis (Gregory *et al.* 2000). Much of children and adolescents' added sugar intakes (or Non-Milk Extrinsic Sugars (NMES)) can be attributed to changes in their beverage consumption patterns (James *et al.* 2004). Intakes of added sugars in the UK are substantially higher than recommended levels for both adults and children. Children, in particular, are high consumers of added sugars, with intakes up to 80% higher than the recommendation. Up to 22% of their added sugars are delivered in the form of non-diet soft drinks (Nelson *et al.* 2007).

2.3.1. Influences on adolescent food choice

Social influences

The social environment plays an especially important role in nutrition through social norms and the availability of healthy food. Social influences on food intake refer to influences that one of more subjects has on the eating behaviour of others, either direct or indirect, either conscious or subconscious (Feunekes *et al.* 1998). Even when eating alone, food choice is influenced by social factors because attitudes and habits develop through the interaction with other people (Feunekes *et al.* 1998).

1) “The influences that people have on eating behaviour of others are not limited to one type, but include a range of influences, for example, modelling of eating behaviour of others, persuasion to consume or avoid eating certain foods, changing the availability of foods for others, and attempting to change someone’s eating attitudes. These influences are embedded in everyday eating behaviour, in family food rules, and in the eating culture as a whole” (Feunekes *et al*., 1998).

2) “Social influences play a role in different time frames. Influences may be exerted during the eating and drinking occasion, such as persuasion, encouragement, and social facilitation of food intake. Alternatively, they may be spread over a prolonged period, such as the effect of cohabitation” (Feunekes *et al*. 1998; supported by Lake *et al.* 2004b).

3) “People are not necessarily aware of the social influences that are exerted on their eating behaviour. If they are aware of this, they might not be eager to admit that their behaviour is influenced by others. This makes it difficult to assess social influences by simply asking them to rate the perceived influences of others” (Feunekes *et al*. 1998). The Health Survey for England 1997 found that the eating habits of 2 to 15 year olds, though not those of ‘young adults’ were related to social class and income (Food Standards Agency, 2003). More recently, foods consumed by 14 to 16 year olds have been found to be similar across socio-economic groups (Food Standards Agency, 2003). Despite this similarity, those in higher social groups report wider exposure to different foods while adolescents in lower social groups report greater independence in

food choices and more responsibility for organising these choices (Food Standards Agency, 2003).

Behaviour

Behavioural patterns in adolescence have been shown to influence dietary behaviour. Studies of adolescents have shown, for example that smoking is associated with reduced intakes of protein, carbohydrate, fruits and vegetables (Crawley & While, 1995). Preoccupation with body weight and diet is also a common occurrence, especially in female adolescents (Barker *et al.* 2000).

In a survey of the 'behaviour, body composition and diets in adolescent girls', aged between 14 to 16 years, (Barker *et al.* 2000) reported that patterns of behaviour found that 19% were regular smokers, meaning that they smoked more than 6 cigarettes a week. These girls were more likely to go out with friends in the evening and less likely to eat breakfast (Barker *et al.* 2000; Samuelson, 2000) and an evening meal with their families (Barker *et al.* 2000).

Late adolescence is a time of increased pressure, such as preparing for their future – studying for examinations for those who remain in education, making independent decisions such as career choices (Wills, 2005). Research in young adults has shown that food intake is perceived to be influenced by stress (Oliver & Wardle, 1999). Data from a UK study of undergraduate students in London, found that most participants reported that stress influenced the overall amount of food that they consumed, with approximately equal numbers eating more (42%) and eating less (38%). The foods most frequently reported as being eaten in greater quantity were sweets and chocolate (70%), cakes and biscuits (60%), and savoury snacks (48%). Foods least likely to be eaten in greater quantity were fruit and vegetables (19%) and meat and fish (9%). Bread was as likely to be eaten less (29%) as more (26%) (Oliver & Wardle, 1999).

Body image and dieting

Various studies of children and adolescents have shown that a sizeable proportion are dissatisfied with their body size and shape (Tiggeman, 2005). This concern increases with BMI and is more prevalent in females than males. The Health Survey for England 2004 found that 20% of 16 to 24 year old females who had a desirable BMI thought that they were too heavy. A significant proportion who were not overweight were trying to lose weight (10% of the underweight and 45% of those with desirable weight) (Butland *et al.* 2007). Research in the US also suggests a rise over time in dieting among adolescent females (Neumark-Sztainer *et al.* 2006).

In a UK study of adolescent females, Barker *et al.* (2000) found that girls who reported being less satisfied with weight were more likely to report lower intakes of percentage energy from fat and higher percentage energy from protein and carbohydrate. Girls who were least satisfied with their weight, reported consuming on average 2055 calories per day and 35% energy from fat, 12% from protein and 53% from carbohydrate. By comparison, girls who were most satisfied with their weight reported consuming on average 2758 calories a day, 38% energy from fat, 11% from protein and 51% from carbohydrate. 'Dieters' tended to watch less television, take vigorous exercise more often and skip breakfast, these effects were independent of girls' social class.

As reported in other US studies, for example, (Watt & Sheiham 1996b; Croll *et al.* 2001; Huang & Volpe, 2004), gender differences in food choice were reported by Neumark-Sztainer *et al.* (1999); these include: boys who said they were trying to eat certain foods to change the way they look, wanted to get taller, more muscular, or gain or lose weight. Girls who discussed this issue did so only in reference to a reduction of body weight (Neumark-Sztainer *et al.* 1999).

<u>Parental influences</u>

Despite the multiple influences on food choices during adolescence, research has found that adolescents perceive their home food environment and parental eating patterns as factors that influence their dietary intake (Hill *et al.* 1998; Neumark-Sztainer *et al.* 1999; O'Dea 2003; Hanson *et al.* 2005). These influences include, parental eating and cooking behaviours, food purchases, rules regarding eating and meals, parental concerns about nutrition, family meal patterns, overall parent-child relations, and familial cultural and religious practices (Neumark-Sztainer *et al.* 1999).

In US focus groups, adolescents associated eating healthful foods with eating family meals (Kelsey *et al.*1998; Neumark-Sztainer *et al.* 2000) and identified parents as important influences on their consumption patterns (Neumark-Sztainer *et al.* 1999; Videon & Manning, 2003) in a number of ways. Similarly, for them to change their eating patterns, the same adolescents noted that they need their parents to encourage healthy eating (Neumark-Sztainer *et al.* 1999; O'Dea 2003). Other studies of adolescents (Woodward *et al.* 1996; Backman *et al.* 2002; Lee & Reicks 2003; Neumark-Sztainer *et al.* 2003) reported the home food environment and parental eating patterns were associated with their dietary intakes. However in studies (Lau *et al.* 1990; Hanson *et al*. 2005) where both adolescents and parents reported their dietary intake independently, the two reports were not associated. Hanson *et al* (2005) suggested that parental report might be a more valid measure of dietary intake since parents may have a better sense for home availability of specific foods as they primarily control what foods are purchased for, and served in, the home (Hanson *et al*. 2005). Other studies (Hearn *et al.* 1998; Baranowski *et al.* 1999; Birch 1999, Kratt *et al.* 2000; Nicklas *et al.* 2001) have indicated that parents and other caregivers can influence the food choices of young children through the types of food made available at home, interactions that take place during meals and eating behaviours they model. However questions remain regarding the degree of influence that parents have on their adolescents' dietary intake (Hanson *et al.* 2005).

2.4. Dietary Assessment Methods

The choice of an appropriate dietary assessment method is critical in designing a nutritional study. Selecting the most appropriate method for a particular study will depend on the nutritional information of interest, the characteristics of the population under investigation and the resources available. The methods most commonly used with children and adolescents are discussed in this section.

Two main factors are important to consider when comparing dietary assessment methods: validity (or accuracy) and reliability. Validity refers to the ability of a dietary assessment method to measure true intake during the period of a study (Goldberg, 2002) and this requires comparison of the method with an external reference method. A reliable measure is capable of producing the same result when used repeatedly in the same circumstances (Nelson, 2000b).

Historically the weighed record is one of the most widely used techniques (Department of Health, 1989a; Gregory *et al.* 1990; Nelson, 1997; Gregory *et al.* 2000). Previously, considered to be the most valid of the measures available requiring all food and drink consumed over a series of days to be weighed. The subject may be interviewed at the end of the recording period to ensure all foods and drinks are recorded along with brand or food type and cooking methods. Nutrient intakes measured by this method have been shown to correlate well with biochemical markers of intake (Bingham *et al.* 1995). A disadvantage of the method is the high subject burden and for this reason diet may be altered and therefore it may not give a true picture (valid measure) of habitual intake (Nelson, 1997).

The estimated food intake method chosen by Hackett *et al.* (1984) in dietary study of Northumberland school children involves the participant recording in a diary everything consumed over a series of days. Instead of weighing all foods consumed the subject estimates portion sizes using household measures, this is usually followed up with an interview to clarify portion sizes using food models, food photographs or food replicas. It has the advantage of being prospective and so does not rely entirely on memory. It lessens the subject burden and may result in a better representation of habitual diet. Hackett and colleagues used five 3-day diaries followed by interviews since they had found the method to be reliable (repeatable) with, for example, reliability coefficient of 0.78 for total sugar intake. Over two three-day diaries the reliability coefficient was 0.59 (Hackett *et al.* 1983). Written records of food intake require a certain level of literacy so may be problematic in some situations and particularly in young children (Baranowski *et al.* 1994) but from the age of 10-12 years, children and adolescents are generally considered capable of reporting their dietary intake reliably using this method (Frank, 1991).

The Food Frequency Questionnaire (FFQ) is a pre-printed list of foods about which participants are asked to indicate the typical frequency of consumption over a stated period, which is typically 14 to 18 days (Cade *et al.* 2002). In contrast to dietary diaries, FFQ's measure a snapshot of usual (not necessarily actual) intake rather than actual current (e.g. weighed) intake. The advantage of the method is it demands minimal subject burden and has the advantage of being able to be conducted as a postal survey. However the scope of the FFQ is limited by the finite number of foods that can be included in the questionnaire and studies have found considerable error in the intake of selected nutrients using this method (Day *et al.* 2001). It has also been shown to overestimate the consumption of several food categories, particularly vegetables in comparison to weighed food diaries (Livingstone *et al.* 1992; Bingham and Day, 1997). It may also prove too difficult for people whose dietary intake varies greatly from day to day to answer questions concerning usual intake over a long time period (Gibson, 1990).

The diet history method is an open-ended interview examining habitual food intake and has been used in studies such as the Young Hearts Project, Northern Ireland

(Boreham *et al.* 2004) and the Amsterdam Growth and Health Longitudinal Study (AGAHLS) (Post *et al.* 2001). It generally involves asking the respondent about usual eating patterns on an average day over the recent past including types of foods, frequency of consumption and portion sizes. The diet history method has been shown to provide a valid estimate of energy intake at the group level compared with a 7 day weighed record (Livingstone *et al.* 1992) and slightly lower than that using a FFQ compared with a 7 day weighed record (Jain *et al.* 1996). Overall this method can be time consuming and is dependent on the respondents' memory (Livingstone and Robson*.* 2000).

The 24 hour recall method is similar to that of the diet history. Participants are asked through a systematic repetition of open ended questions to recall and describe every item of food and drink they have consumed over the last 24 hours (Nelson, 2000b). In young children this is usually carried out with the parents, but thereafter the ability of children to self-report their food intake increases. The interviewer may assign average weights to the foods or the subject may estimate portion sizes using food models or photographs (Nelson *et al.* 1997; Foster *et al.* 2006). The main advantage of the 24 hour recall method is that it is quick and easy to administer (Nelson, 2000b). However, as with the diet history method, description of the foods consumed as well as portion size is dependent on participants memory recall and is therefore prone to omissions (Nelson, 2000b).

There are a number of methods available to validate energy intake such as direct comparison with estimates of energy expenditure derived from heart-rate monitors, accelerometers, and physical activity questionnaires all of which have their own sources of error. Energy expenditure measured using the doubly labelled water (DLW) method is considered the gold standard in free living conditions (Livingstone and Black, 2003) but this is very expensive.

Under-reporting of dietary intake is a common source of error in epidemiological studies (Nelson, 2000b). Energy needs are determined largely by BMR with additional requirements for energy expenditure from physical activity, and in the case of children, additional requirements for growth. In the absence of direct measures, BMR can be estimated using the age and sex appropriate equations of Schofield *et al.* (1985b). A person whose energy intake equals their energy expenditure is said to be in 'energy balance'. Assuming energy balance, estimates of energy requirements could be based on measurements of either energy intake or energy expenditure. Measurements of energy intake are less reliable than direct measurements of energy expenditure and validation studies have demonstrated that a bias in dietary reporting is highly probable (Torun *et al.* 1996). For this reason, estimates of energy requirements are usually based on measurements of energy expenditure. Total energy requirements can be expressed as a multiple of BMR (Torun *et al.* 1996). This is a factor referred to as the *physical activity level* (PAL) and is calculated as the ratio of measured total energy expenditure (TEE) to BMR.

Torun *et al.* (1996) defined lower and upper cut-off points as 1.39 and 2.24 x BMR for males and 1.30 and 2.10 x BMR for females as reasonable estimates of energy requirements of children and adolescents aged 6 to 18 years. A ratio of 1.0 indicates that a person has reported consuming the minimum energy requirement for the body to function at rest. If usual or habitual dietary intake is reported it would be expected that EI would be broadly equivalent to energy expenditure (EE), assuming energy balance (Hill, 2006).

As discussed there are a number of methods for the assessment of dietary intake, yet in practice, it is notoriously difficult to achieve an accurate measure and assessment is subject to numerous sources of error (Livingstone *et al.* 1992). Nevertheless dietary assessment can provide a valuable estimate of food and nutrient intake in free-living subjects.

2.5. Tracking

Tracking has been defined as the maintenance of relative position in rank of behaviour over time (Kelder *et al.* 1994), such that from a public health perspective participants who rank highly for disease risk (Twisk, 2003) (from adiposity and/or dietary behaviour for example) at a young age are likely to maintain their ranks through into adulthood (Boreham *et al.* 2004).

One of the main problems in tracking analyses is how to evaluate the magnitude of tracking and with it the difficulty to conclude whether tracking or not exists. Several methods are used to assess tracking such as the odds ratio and regression modelling for example (Twisk, 2003). The two most common methods are using correlation coefficients between baseline and subsequent measurements (Kelder *et al.* 1994) or by grouping the baseline data by rank into tertiles or quartiles and determining the proportion of participants maintaining their ranking at follow-up measurement (Boreham *et al.* 2004).

Conclusions are often based on the significance of the correlation coefficient, but it is much more important to consider the magnitude of the tracking coefficient (Twisk, 2003). However this in turn also depends largely on the length of time interval with shorter intervals usually yielding higher, but not necessarily ‘better’ coefficients than over longer periods (Twisk, 2003). Tracking is also influenced by chance and it is argued that the Kappa test (*k*) can be used in order to avoid chance or random measurement error. That is because *k* can be seen as the proportion of agreement between two measurements over time, corrected for the expected proportion of agreement caused by chance (Altman, 1991). Measurement error should also be considered when interpreting tracking coefficients, for example tracking coefficients tend to be weaker with larger measurement errors such as dietary intake compared with more reproducible factors such as BMI (Twisk, 2003). Caution should also be taken when interpreting the results of tracking analysis based on percentile groups.

For example, while it is of interest to assess the proportion of subjects remaining in a 'risk' group over time (Twisk, 2003) it is reported that subjects with a stable high body weight over time are less likely to develop cardiovascular problems than those with an increase in body weight over time (Guo and Chumlea,1999). Therefore not only subjects maintaining a certain 'risk' group should be evaluated but also the proportion of subjects that increase to the 'risk' group over time (Twisk, 2003).

2.5.1. Tracking of body size

The prevalence of obesity in children and adolescents has almost tripled in Britain in the past 20 years, as it has in the United States (Wardle, 2006). Longitudinal data are critical to understanding the patterns of obesity development over time, the permanency of obesity at each age, and the ideal points for intervention (Gordon-Larsen *et al.* 2004). Several longitudinal observational studies have been conducted to examine the tracking patterns of children's BMI (Wang *et al.* 2000; Magarey *et al.* 2003; Fuentes *et al.* 2003). However few studies have focused on tracking of health-related variables such as overweight and BMI from childhood to adolescence (Johannsson *et al.* 2006; Wardle *et al.* 2006). Adolescence has been identified as a critical period for the development of persistent overweight and obesity on the basis of the strong evidence for tracking of adolescent adiposity into adulthood (Rolland-Cachera *et al*, 1987; Serdula *et al.* 1993; Power *et al.* 1997; Lake *et al.* 1997; Whitaker *et al.* 1997; Craigie *et al.* 2004). Furthermore adolescent obesity is associated with all the long term risks of adult obesity and may carry additional risks for metabolic disorders (Mahoney *et al.*1996; Berenson *et al.* 1998a; Must & Tybor, 2005).

The normal pattern is for BMI to decrease from ~2 years of age until 5 or 6 years of age and to increase thereafter (Malina, 2004 in Krebs, 2007). This early decrease in BMI reflects a corresponding decrease in subcutaneous fat and the percentage of body fat, a pattern termed as the 'adiposity rebound'. It coincides with the period between the ages of 4 and 7 years when BMI reaches its lowest point and then begins to increase through the remainder of childhood and into young adulthood (Dietz, 1997).

In a European study of children and adolescents, Johannsson *et al.* (2006) reported that the children who were overweight at age 6 years were more likely to be overweight at age 9, 12 and 15 years. A greater persistence of overweight were shown between ages 6 and 9 years (72%) than between 9 and15 years (54%) or between 12 and 15 years (58%). However the magnitude of tracking was higher as the children got older with an odds ratio of 21.8 for being overweight from age 6 to 9 years and an odds ratio of 27.2 from age 12 to 15 years.

The health and behaviour in teenagers study (HABITS) is a five year longitudinal study of English children, established in 1999, designed to investigate the development of cancer related risk factors, including smoking and obesity (Wardle *et al.* 2006). Data collection continued annually from year 7 (age 11-12) to year 11 (age 15 -16). The prevalence of overweight or obesity was high at age 11 years, 18.6% (15.6% males; 23.1% females) were overweight and 5.5% (4.6% males; 6.7% females) were obese. At age 16 years 16.9% (14.4% males; 20.4% females) were overweight and 6.8% (5.7% males; 8.3% females) were obese, 10% of participants remained overweight and 6% remained obese. Adiposity tracked strongly over time and BMI correlations from year to year were greater than 0.9 at one and two year and above 0.8 for three and four year intervals. In agreement with Johannsson *et al.* (2006) this indicates that the children who are fatter than average at age 11 years were likely to remain fatter at age 15 years. Transitions from overweight or obese to normal weight showed that if excess adiposity is present at age 11 years, it is highly likely to persist. In this sample very few students who were obese in year 7 later changed to normal weight status. Thus the high risk period for onset of persistent obesity may be in the pre-adolescent years, which has important implications for targeting preventive efforts (Wardle *et al.* 2006). However the value of intervention in late childhood and adolescence must not be underestimated (Johannsson *et al.* 2006). In a systematic review of the literature from 1985 to 2005 Singh *et al.* (2008) found increased risk for an overweight or obese youth to become overweight or obese in adulthood. Several studies reported that persistence of overweight was greater with increasing level of overweight (Serdula *et al.* 1993; Guo *et al.* 1999; Laitinen *et al.* 2001; Engeland *et al.* 2004; Field *et al.* 2005). Overall the magnitude of tracking was higher with increasing age (Singh *et al*. 2008), a finding supported by other authors (Wright *et al.* 2001; Gordon-Larsen *et al.* 2004; Johannsson *et al.* 2006). Guo *et al.* (2002) analysed lifelong data from the Fels Longitudinal Study and estimated the probabilities of being obese at age 35 years as ≥ 60% from age 12 to 20 years in females, and for males 40% to 60% from age 11.5 to 16 years and ≥ 60% from age 17 to 20 years. The author went onto suggest if individuals end their adolescence with moderately elevated BMI, then the likelihood of obesity in later adulthood (for example, age 35 years) was greater.

The National Longitudinal Adolescent Study (Add Health) consisted of 14, 438 adolescents, a nationally representative, school based study of US adolescents age 13 to 20 years (Gordon-Larsen *et al.* 2004). Over the five year period between wave II (13y-20y) and wave III (19y-26y) 9.4% of the total sample was obese as adolescents and young adults and 12.7% of those non-obese at wave II became obese at wave III. In agreement with other studies (Wright *et al.* 2001) for the total sample, younger adolescents were less likely to become obese as young adults (compared with older adolescents) and were twice as likely to become non-obese as with their older counterparts. These data indicate a high incidence and maintenance of obesity during transition from adolescence to young adulthood. Conversely, despite the rapid linear growth of males after puberty a small proportion (14.4%) of adolescents (aged 13-20y) moved out of the obese category as they became adults (19-26y). The results of this study mirror many smaller studies (Serdula *et al.* 1993; Srinivisan *et al.* 1996; Power *et al.* 1997) that display a significant tendency for childhood and adolescent overweight to persist or track into adulthood. Childhood obesity is moderately predictive whereas adolescent obesity is highly predictive of adult obesity (Whitaker *et al.* 1997; Guo *et al.* 2002). These findings indicate that the transition between adolescence and young adulthood appears to be a period of increased risk of development of obesity for life.

2.5.2. Tracking of energy and macronutrients

Strong tracking of anthropometric variables relating to body weight and adiposity and biological measures such as total sum of skinfolds have been consistently reported (Serdula *et al.* 1993; Srinivisan *et al*, 1996; Power *et al*, 1997; Twisk *et al.* 1997; Robson *et al.* 2000; Wright *et al.* 2001; Gordon-Larsen *et al.* 2004; Boreham *et al.* 2004; Craigie *et al.* 2004; Wardle *et al.* 2006). In contrast, the evidence for tracking, or otherwise, of nutrient intakes of adolescents (age 11 to 17 years) has been somewhat scarce and inconsistent.

In several studies of younger children fair to moderate tracking of certain nutrients have been reported. One study, which examined the extent of tracking of nutrients in the diets of 181 children initially aged 45-60 months, reported tracking coefficients for calcium (Stein *et al*. 1991). Despite substantial day-to-day variation in intake, the authors concluded that the underlying diets, assessed using repeated 24 h recalls, of the pre-school children did track well over time. A later study, which used a series of 3 d estimated food diaries to assess the diets of seventy-three children from 3-4 years to 7-8 years of age, also found evidence of nutrient tracking from the pre-school years to school age (Singer *et al*. 1995). However, as the subjects in these studies were surveyed at young ages when diet is highly likely to be controlled by parents or guardians, this is probably to be expected. In contrast evidence of nutrient tracking in older children and adolescents is less consistent. For example, Boulton *et al*. (1995) reported tracking of dietary energy, fat and calcium in an Australian cohort from the age of 1 to 15 years. Diets in that cohort were assessed using 4 d weighed records. It was apparent that children who were `big eaters' at a young age remained so, but that those who had lower energy intakes when younger became more evenly spread across the distribution of intakes over time.

More recently, The Young Hearts Project is an ongoing longitudinal study evaluating a range of behavioural and biological risk factors for CVD in young people living in Northern Ireland (Boreham *et al.* 2004). Initial school based screening (YH1) was conducted in 1989/1990 and surveyed 1015 adolescents. These were a combination of age 12 (251 males, 258 females) and 15 year olds (252 males, 254 females). In 1992 and 1993 (YH2) the 12 year old cohort of YH1 were reassessed at age 15 years (Robson *et al.* 2000). Between 1997 and 1999 all YH1 subjects were invited to take part in YH3 aged 20-25years (Gallagher *et al.* 2002). Boreham *et al.* (2004) reported on the findings of participants for whom complete data were available (245 males and 231 females) at age 15 (combined YH1 and YH2) and at young adulthood (age 22 -25 (mean 22y) (YH3)).

At all study time-points diet was assessed by the diet history method as described in Chapter 2.4. Reported energy and macronutrient intakes were calculated using UK food composition tables (WISP, Tinuviel Software, Warrington, UK). For each dietary and anthropometric measurement participants were ranked into low, medium and high categories at age 15 and 22 years. Using this method of classification provided a broad picture of the relative changes in a particular variable over time, such that a matrix with relatively small off-diagonal elements provides evidence of ‘good’ tracking. The extent of tracking was summarized using Kappa (k) statistics and interpreted according to Altman, (1991) as follows: k ≤0.20 poor tracking, k 0.21-0.40 fair, k 0.41-0.60 moderate, k 0.61-0.80 good, and k 0.81-1.0 very good.

At age 15 years, Robson *et al.* (2000) reported poor tracking of EI (MJ/d) for males (k=0.18) and fair for females (k=0.24). With the exception of protein (EI%) (k= 0.25), the tracking macronutrients in males from age 12 to age 15 years was poor (k< 0.20).

For females, protein intake (g/d and % energy) exhibited a fair degree of tracking, but this was not evident for other macronutrients. At age 22 years Boreham *et al.* (2004) also reported poor tracking (k<20) for all nutrient intakes between age 15 and 22 years for both males and females. Another study, the Amsterdam Growth and Health Study, (AGAHLS) was a 20 year longitudinal study covering adolescence to adulthood (Post *et al.* 2001). During the period 1976 to 1996-7 (20 years) 73 males and 91 females were measured 8 times from age 13 to 33 years. During adolescence (13-17 years) four annual assessments were taken, starting in 1977 and ending in 1980. At the age of 21 years the fifth measurement was carried out in 1985. The sixth and seventh measurement were at the age of 27 and 33 years in 1991 and 1996-7. Dietary assessment was also (Boreham *et al.* 2004) measured by detailed cross-check dietary history interview and during adolescence by parental questionnaire. Nutrient intake was calculated with the use of the Dutch food consumption table (Stichting Nederlandse Voedingsstoffen Bestant, 1996 in Post *et al.* 2001). Tracking of dietary factors was examined by generalised estimating equations (GEE) (Twisk *et al*. 1997). Between age 13 and 33 years significant (p<0.05) stability coefficients of energy intake and all macronutrients were described as low to moderate stability of dietary intake with values ranging from 0.28 to 0.45 with the highest being for EI relative to body weight (KJ/kg/d) (0.52) Indicating, in agreement with the previous study (Robson *et al.* 2000; Boreham *et al*, 2004) that dietary intake during adolescence seems to be a fairly weak predictor of dietary intake in the adult. These findings were comparable with those of other lifestyle variables such as daily physical activity (0.34) (Boreham *et al.* 2004) but considerably lower than biological measures such as total sum of skinfolds (Twisk *et al.* 1997) and BMI (Chapter 2.5.1).

2.6. Measuring physical activity

Physical activity is defined as "any bodily movement produced by skeletal muscles that result in energy expenditure" (Caspersen *et al.* 1985) and therefore incorporates all daily activities. In children movement is often more sporadic and multi-dimensional, and daily activity patterns are commonly more varied than in adults. Until relatively recently measurement of habitual physical activity has been challenging and published literature of reliable methods of measurement in adolescence (age 16-18 years) is scarce (Welk *et al*. 2007). Recent technological developments have provided the means for objective measures of physical activity.

Physical activity dimensions include intensity, frequency, and duration which together make up the total volume of activity. Another important dimension of physical activity is the type of activity such as walking and cycling (Corder *et al.* 2008). The research question being investigated in any particular study is crucial to identifying the most appropriate assessment method(s) for physical activity.

Subjective methods include questionnaires, interviews, activity diaries (logs) and direct observation. The latter is useful for the assessment of physical activity in controlled situations and as a valid criterion, but the obtrusive nature and substantial investigator burden makes it unsuitable for use in free-living conditions. The accuracy of information collected by subjective instruments is influenced by the ability to accurately recall all relevant details retrospectively, and may also be influenced by perception of the study (Corder *et al.* 2008).

Objective methods for assessing physical activity involve the measurement of physiological or biomechanical parameters and use this information to estimate physical activity outcomes (Corder *et al.* 2008). Accelerometry is the most commonly used objective method of physical activity assessment in youth (Corder *et al.* 2007). Accelerometers provide a valuable means of measuring physical activity levels and patterns in free-living populations, offering an objective addition or alternative to diaries or other methods.

An accelerometer quantifies one or more dimensions of movement of the body and data is expressed as “counts” over a period of time (Epoch) ranging from seconds to a minute. In children 5s epochs are recommended given the short duration of their activity bouts. However, in all age populations the epoch length used should ideally be as short as possible because data can always be reintegrated into a longer time frame but not vice versa (Corder *et al,* 2008). Extensive studies using accelerometers have been undertaken previously (Puyau *et al.* 2002; Trost *et al.* 2000), but this literature is limited to children, young adolescents and adults. Uniaxial accelerometers are unobtrusive, fit easily under clothing and are easily manageable across periods of several days. They allow informative group comparisons of physical activity volume, but also offer a means of assessing individual activity profiles (Cooper *et al.* 2000).

There are however, limitations to the use of accelerometers. For example they are unable to detect the type of activity and must be used in combination with physical activity diaries or logs to record the types of activity that have taken place. Accelerometers provide a valid measure for activities such as walking or jogging (Troiano, 2006). But it is well recognised that whilst vertical acceleration of the body can be measured accurately, waist-mounted accelerometers do not reflect the external work performed in such activities as pushing or lifting objects. Neither do they accurately estimate activities such as upper body movement, cycling or stair climbing (Puyau *et al*. 2002, Troiano, 2006). In addition, the instruments are not waterproof, and must be removed prior to swimming or other water sports. The failure to accurately measure these activities will lead to underestimates of the activity of individuals who regularly participate in such activity (Cooper *et al.* 2000). Accelerometer data, commonly expressed as “counts” provide an estimate of activity volume, however the categorisation of activity intensity or estimates of energy expenditure rely on further validation studies (Corder *et al.* 2007). Intensity cut-off points for the CSA accelerometer have been determined in young adults (Freedson *et al.* 1998). However the prediction equations derived from treadmill protocols under laboratory conditions may not be representative of free-living conditions. Despite these limitations, accelerometry provides a promising means of physical activity measurement, particularly in the obese whose primary mode of activity is walking. When used in combination with heart rate monitoring (Rennie *et al*. 2006) accelerometry has potential for more accurately measuring activities such as cycling.

3. METHODOLOGY

Chapter overview

Introduction

A series of three cross sectional dietary studies were carried out between 1980 and 2000 (Figure 3.1). These studies involved adolescents aged 11-12 years of age (year 7) from seven middle schools located in Northumberland, four in Ashington; one in Newbiggin by the sea; and two in Morpeth. All year 7 pupils were asked by their head teachers if they wished to volunteer to take part. This was followed by a letter to their parents providing details about the study and asking them if they wished to consent to their child taking part. Of the 661 pupils invited to participate, 450 volunteered and 424 completed all aspects of the study (Fletcher *et al,* 2004). In 2005/6, the 424 young people (now aged 16-18 years) who completed all aspects of the 2000 study at 11-12 years of age were invited to take part in this longitudinal follow-up study (Figure 3.1). All activity for tracing and recruitment was undertaken by Alison Hossack as part of her PhD studies and the methods for tracing and recruiting these potential participants are illustrated in Figure 3.3.

This chapter describes the methods used to search and recruit these young people using data from the original study at age 11-12 years (Fletcher, 2003). The chapter will also explain the methods used in the assessment of dietary intake; the measurement of physical activity and lifestyle and the collection of anthropometric data of these young people.

3.1. Search and recruitment of potential participants

3.1.1. Ethical approval

Due to the nature of the study which did not include intrusive measurements such as blood samples or the collection of sensitive information, did not include NHS patients, NHS personnel or NHS premises this work could not be submitted to COREC for an ethical opinion. The study was approved by Newcastle University Ethics Committee. A letter (Appendix 1) explaining the background, details and protocol of the study was sent to the Director of Education at Northumberland County Council which invited him to comment on any aspect of the study. Consent was given by the Director for schools to be re-contacted and for the study to proceed

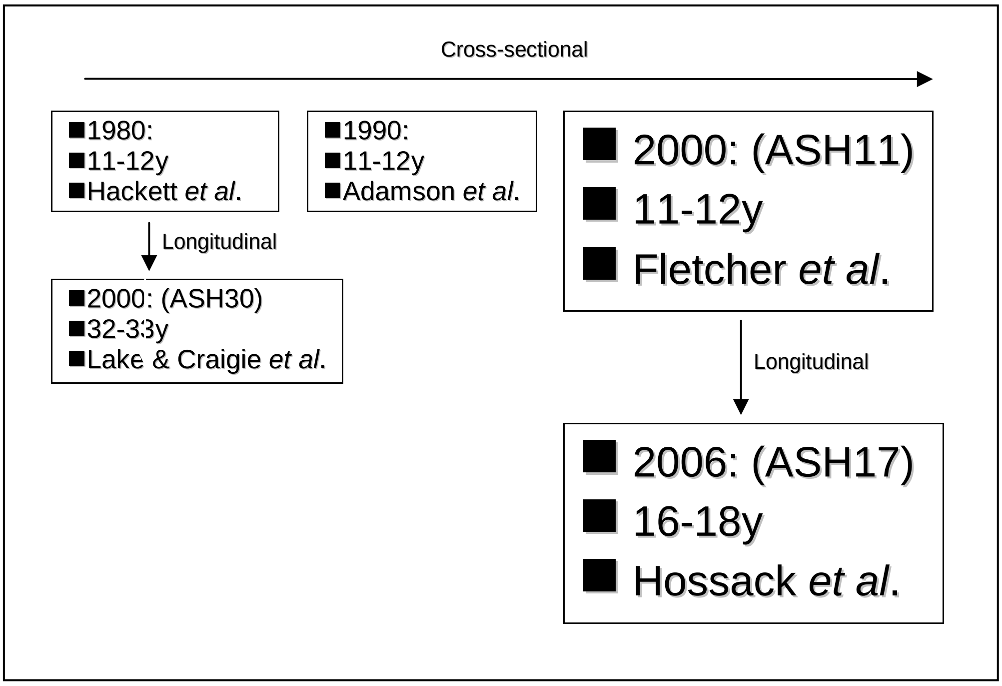

Figure 3.1 Background to selection of participants

3.1.2. Locating the potential participants

Whilst home addresses were provided by some parents of participants', all aspects of the 2000 study were carried out in the aforementioned Middle schools and none of the participants were contacted at their home address. The process used for tracing these young people in 2005/6 is illustrated in Figure 3.3. A logo (Figure 3.2) was designed specifically for this project and was used in all further correspondence.

Figure 3.2 Northumberland Young Peoples Diet Food Survey logo

<u>Contacting Middle schools</u>

Each of the seven schools was sent a letter in November 2004 (Figure 3.3), reminding them of the findings of the 2000 study, and introducing the present study. This letter was followed up with a telephone call to the head teacher of each of the seven schools, requesting their assistance to help trace the participants of the 2000 study. All of the schools provided details of which High school the children of the 2000 study may have moved on to after leaving their Middle school.

<u>Contacting High Schools</u>

Based on the information given by the Middle schools, in January 2005, the four main high schools (*King Edward VI School*, Morpeth; *St Benet Biscop Catholic High School*, Bedlington; *Ashington Community High School and Sports College* and *Hirst High School Technology College*, both of which are in Ashington) were sent a letter of introduction (Appendix 2) (see also Figure 3.3). This provided an overview of the previous study carried out in 2000, and indicated that we would be contacting them in the near future with a view to discussing this study further. The letter was followed by telephone calls to the head teachers to arrange a meeting to provide them with further information about the study.

Each of the four high schools was visited by Alison Hossack (PhD student) and Dr Ashley Adamson (Project supervisor) in February 2005. This provided an opportunity to discuss the details of the study with the person who was to be our main contact at the High school.

To enable the schools to assist in our tracing of these young people, who were now potentially in sixth form/year 12, a database detailing names, date of birth, postcode, and previous middle school was emailed to each of the high schools requesting confirmation of the whereabouts of these young people.

All of the High schools agreed to help with the study, and returned the completed database confirming which of the students were currently in sixth form at their school. Details of location are summarised in Table 4.1.

Contacting School leavers

For the remaining young people who were not at these four High schools, a search was made through "Connexions[*], Northumberland" (Figure 3.3). Letters explaining why we were contacting them, along with confirmation of address forms and a post-paid envelope, were sent to respondents by Connexions (n=142). The remaining respondents were contacted via the High schools by staff and students; 2 were deceased.

[*] NB: Connexions Northumberland is a confidential advice and support service for young people aged 13 to 19 years (www.connexions-tw.co.uk).

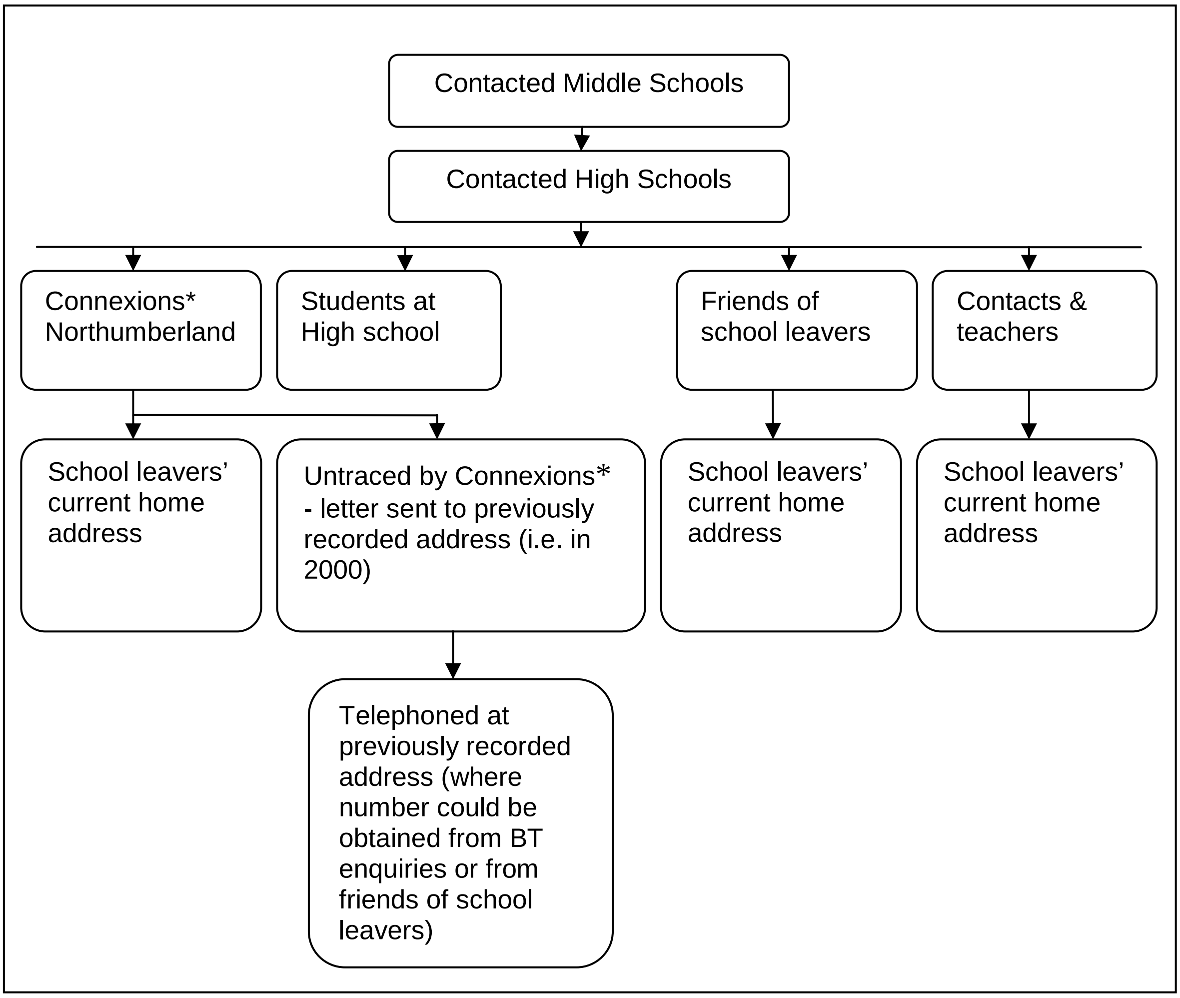

Figure 3.3 Flow diagram to show the procedure for locating the study participants.

By June 2005, n=90 of the young people who were sent a letter via Connexions had not returned their confirmation of address form. A second letter was sent to these respondents for whom an address was held on file from the 2000 study. In some cases the respondent was confirmed by other participants of the study to be still residing at the previous address. Where the respondent was not *confirmed* to be at the previous address, a letter was sent regardless, with the prospect that some contact may be made. Efforts were made to contact by telephone, the young people who did not respond to these letters. Telephone numbers were obtained where available, from BT enquiries where previous addresses or postcodes were recorded, and from current participants of the study who were able to give telephone details for friends.

* NB: Connexions Northumberland is a confidential advice and support service for young people aged 13 to 19 years (www. connexions-tw.co.uk)

3.1.3. Recruiting the participants

<u>Participants remaining at High schools</u>

The schools were re-visited in March and April 2005, where a group meeting was arranged to present details of the study and to invite the students to participate.

All of the students who attended the group meeting were given a letter (Appendix 3), which confirmed details of the study and what would be required of them. Also enclosed with the letter was a consent form (Appendix 4). The respondent was invited to return this as confirmation of their desire to participate in the study, or inform us that they did not wish to participate in *this* study. It was signed by the respondent, and a parent or guardian and returned in a post-paid envelope to the research office. In cases were students were absent or had recently left the school, information packs were forwarded to them, either by fellow students or teachers.

By June 2005, less than 25% of respondents had consented to participate in the study. At this stage other methods were introduced in an attempt to increase recruitment.

These included:

- Placing A2 size posters (Appendix 5) in prominent places around the schools (5 in each school).
- Sending follow-up slips (Appendix 6) to the students via the school register.
- Word of mouth.
- Asking other participants to pass on messages to their friends.
- Direct approach in school to students in the relevant year group, asking if they took part in the original survey and if so did they want to take part in this survey;
- Via a sheet, which teachers asked the students to sign to say whether they would like to participate or not. This gave an opportunity for young people to state they did not wish to take part without completing a form. If they did wish

to take part, a telephone number was obtained and a consent form was signed at the first appointment, prior to initiation of data collection.

Where the respondent had left school by this date, telephone numbers were obtained and the respondents were telephoned to establish their intention. Where telephone numbers were not available, follow-up letters were sent via the schools to the respondent's home address.

Participants who have left school

Young people who were contacted via Connexions and expressed an interest in receiving further information about the study (i.e. returned their confirmation of address form) were sent an envelope containing an information letter, opt in/opt out consent form and post-paid envelope. The consent form was returned to the Human Nutrition Research Centre office at Newcastle University, and an appointment was made using the telephone number given (on the confirmation of address form). If the consent form was not returned within one month, the respondent was contacted again by telephone to establish their intention.

An overview of data relocating and recruiting participants is given in Chapter 4.1.

3.2. Overview of data to be collected

This chapter is arranged in the order of how the data was collected and for reference, the process is shown a flow diagram in Figure 3.4.

All participants who had taken part in the 2000 study had been allocated a unique ID, this ID was also used to identify participant data in this follow-up study.

Assessment of dietary intake

Dietary intake was collected at age 11-12 years in 2000 and at age 16-18 years using the same methods. Data for mean total energy intake, carbohydrate (sugars), fat (saturated fats) were analysed and compared with those of the 2000 study. Details of these methods used are described in Chapter 3.3.

Measurement of physical activity

A direct measure of physical activity was obtained at age 16-18 years using Actigraph activity monitors. A detailed description of how these data were collected is given in Chapter 3.4.

Questionnaire - Knowledge and attitudes to: food intake; physical activity; body composition

A 29 item electronic questionnaire was used to record qualitative and quantitative data on the knowledge, perceptions, attitudes and behaviour of these young people at age 16-18 years. The methods used in the development and execution of the questionnaire are discussed in Chapter 3.5.

Socioeconomic status

Social class was established in 2000 using head of household occupation and classified using two methods: the ‘simplified social class’ method based on the standard occupational classification (SOC) of 1990 (Office of National Statistics, 1990), and the most recent system SOC2000 (Office of National Statistics, 2000). However, all reported data at age 11-12 years were analysed using the ‘simplified social class’ method (SOC 1990) and, for continuity, this is the method used in all analyses reported herein. Due to the relatively small sample size, for the purpose of analyses, participants were grouped into 4 social groups ‘high’ (social classes I & II),’middle’ (III), ‘low’ (IV & V) and ‘unclassified’ (Fletcher, *et al*. 2004). ‘Unclassified’ generally refers to participants for whom insufficient information was provided to enable classification.

Collection of anthropometric data

Height and weight were measured in both 2000 and 2006. In 2006, measurements were extended to include waist and hip circumference and body composition (i.e. percent body fat). The methods used for anthropometric measurement are described in Chapter 3.6.

3.2.1. Time one, data collection (T1)

T1 (Figure 3.4) data collection commenced on 25th April 2005 and concluded in January 2006.

School participants: To arrange appointments for delivery and collection of the diary and activity monitor and to agree convenient days for completing the diary, participants were telephoned using the number given on the consent forms (see Chapter 3.1.3). To assist in arranging convenient appointment times i.e. during school hours, timetables were obtained from each of the four High schools. Whilst the majority of appointments for school participants were held at the schools, some participants were on study leave, hence the appointment (visits 1 and 2) (Figure 3.4) was held at their home.

School leavers: Participants who had left school were contacted in the same way as those still at school, and the appointments (visits 1 and 2) (Figure 3.4) took place at college, their place of work, or home address.

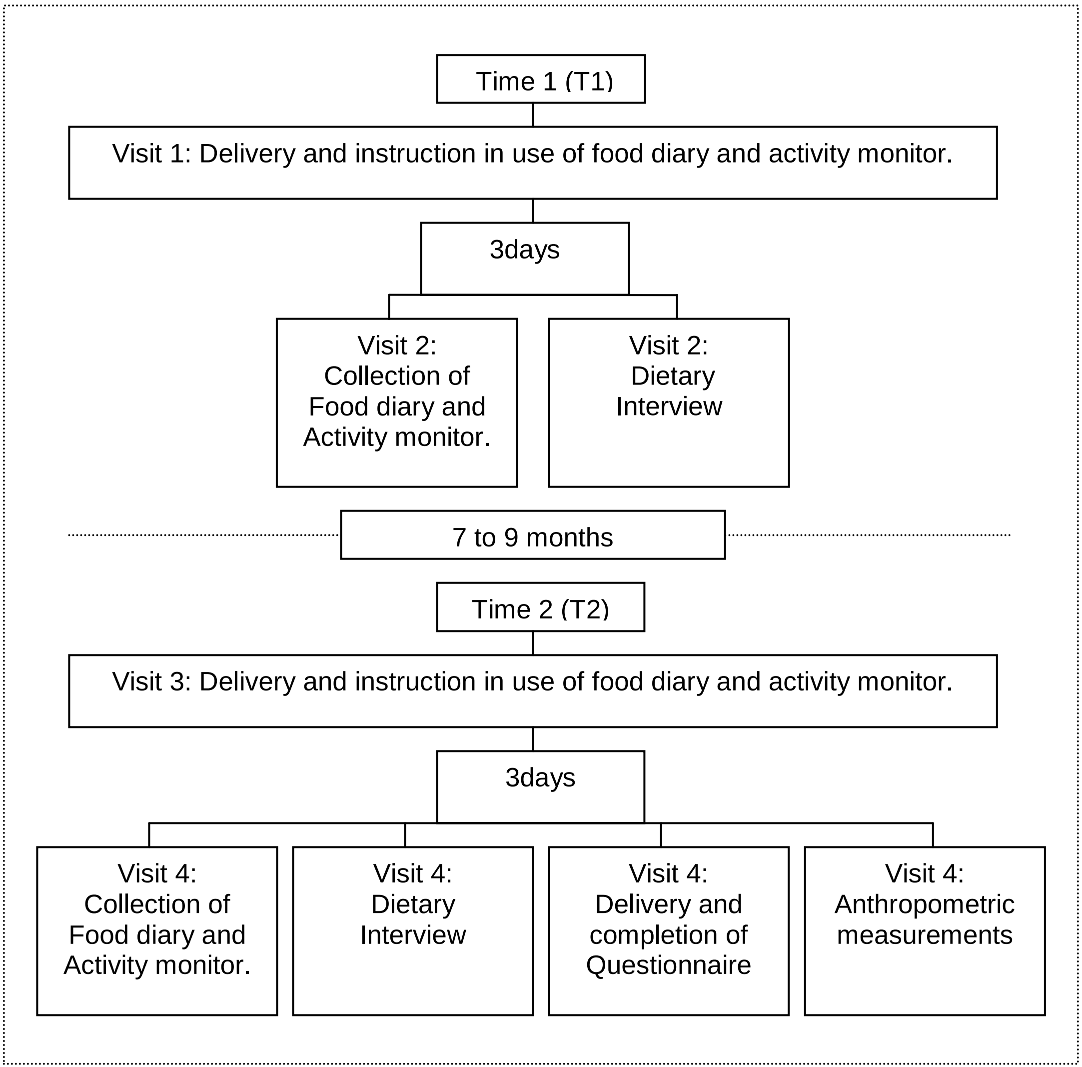

Figure 3.4 Overview of process of data collection

All appointments (visits 1 and 2) (Figure 3.4) were structured to make the most efficient use of time, for example visiting houses in the same area and holding group meetings at schools (visit 1 only) (Figure 3.4). Dietary data were recorded by participants (Chapter 3.3) for three days and collected on the fourth day (visit 2, Figure 3.4). However, data were not collected on Sundays, and collected on Saturdays only when necessary, from participants who had left school. Therefore, deliveries (visit 1) were not made on Wednesdays and on Tuesdays only to participants who had left school.

3.2.2. Time two data collection (T2)

T2 data collection commenced January 2006 and concluded in July 2006.

To arrange appointments for T2 (Figure 3.4), respondents were re-contacted by telephone on the number(s) given in T1. Where the respondents had changed their telephone numbers, an alternative number was given by friends of the respondents' or a visit was made to their homes to arrange an appointment (visits 3 and 4).

School participants: As in T1, the majority of appointments (visits 3 and 4) for school participants were held at the schools. However as some participants were on study leave, the appointment was held at their home. A number of respondents who were at school in T1 had left school by T2, thus alternative arrangements were made for appointment, such as in a place of work, at home, at college or at the school by prior arrangement with the school contacts.

School leavers: As in T1, appointments (visits 3 and 4) with these participants took place at college, their place of work, or home address.

3.3. <u>Assessment of dietary intake</u>

The same method of dietary assessment was used in both the 2000 study and this follow-up study: Participants were asked to record their dietary intake (Chapter 3.3.3) in two 3-day food diaries with each dietary record being 7 to 9 months apart. At each stage of data collection (T1 and T2) (Figure 3.4) participants were provided with a new A5 size food diary designed for this project (Figure 3.5 and Appendix 7). Immediately after completion of the food diary the participant was interviewed to clarify their diary content and to ascertain portion sizes of foods eaten (Chapter 3.3.4). The three days recorded in each diary were consecutive, but the days of the week were chosen at the convenience of participants and the second diary was completed on different days from the first diary. This method has been used extensively (Hackett *et al.* 1984; Adamson *et al.* 1992a; Fletcher *et al.* 2004) and the validity of the method and reliability of the data obtained in children have been assessed (Hackett *et al*. 1983, 1985; Adamson *et al.* 1992). This method is discussed in more detail in the following sections.

3.3.1. Design of food diary

The food diary (Appendix 7) was compiled, combining the formats used in the 2000 study of 11-12 year olds (Fletcher, *et al*. 2004) and the 2000 follow-up study of 32-33 year olds (ASH 30 study) (Craigie, *et al*. 2004 & Lake, *et al*. 2004b) (Figure 3.1), but also to have an overall appearance which would be appropriate for the age-group to be studied. The front cover of the diaries contained the logo (Figure 3.2), participants ID, diary number (T1 or T2), and space to record the dates during which dietary information was collected. Instruction on how to complete the diary was given on the inside cover and the appointment date of collection was recorded on the first page. Each diary consisted of an example page (Figure 3.5) and eight pages on which to record intakes of food and beverages. Each page included: an area to record the day and date of study, the time at which items were consumed, details of the items consumed in terms of brand name, flavour and (if in a package) the weight on the package, how the item was cooked, the amount consumed, excluding leftovers, and an area was reserved for ‘office use’ on which the results of the interview (Chapter 3.3.4) were recorded. The inside back cover of the diary was allocated for participants to record recipes. Space on the back cover (Figure 3.7) was provided for participants to comment on what they had eaten during the 3 days e.g. whether they had eaten as they usually would and a table for the interviewer to record participants’ anthropometric measurements (Chapter 3.6).

The food diary was subsequently amended to include space for recording activity monitor data (Chapter 3.4). Labels were printed (Figure 3.6) and placed on the bottom of each right hand page of the diary (Figure 3.5).

Day & Date…………………………………. Start each day	on a new sheet Volunteer ID……………………						
Time	Food & Drink include: Brand name, flavour and weight *Enter each food item on a new line*	Cooking method e.g. fried, grilled, poached, etc.	Amount eaten Excluding leftovers. e.g. cup, slice, teaspoonful, portion of family meal	Office use	Food Photo Office use	Weight Office use	Food Code Office use
7.30am	*Kellogg's Frosties*		*1 bowl full*				
	Tesco semi-skimmed milk		*$\frac{1}{2}$ pint*				
10.35am	*Pringles – Cheese & Onion*		*$\frac{1}{2}$ 200g tube*				
	Can diet Coke		*300 ml*				
12.30pm	*Tesco Medium white bread*		*2 medium slices*				
	Flora margarine		*2 tea spoons*				
	2 slices Bernard Matthews Turkey ham		*2 slices*				
	Granny Smith apple		*1 medium*				
5.45pm	*Spaghetti Bolognese – (see recipe section)*	*Home recipe*	*$\frac{1}{2}$ of amount cooked*				
	Asda Spaghetti	*Boiled*	*$\frac{1}{2}$ bowl full*				
	Tap water		*1 large glass*				
	Ribena blackcurrant		*$\frac{1}{4}$ pint*				
10.00pm	*Cadbury's hot chocolate with water*	*Boiled*	*1 mug*				
	McVities Jaffa cakes		*4 biscuits*				
Have you taken any supplements or non prescribed medication e.g. Vitamin tablets, etc. Please specify……………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………							

Figure 3.5 Example page of food diary

Time wearing your actigraph.

Time on: ***8am*** **Time on:** ***2. 15pm*** **Time on:** **Time on:**

Time off: ***1pm*** **Time off:** ***10pm*** **Time off:** **Time off:**

Reason: ***swim*** **Reason:** ***Bed*** **Reason:** **Reason:**

Figure 3.6 Example of activity data label

Food Diary: Any Comments?

Have you any comments about what you have eaten during the 3 days?
…………………………………………………………………………..
…………………………………………………………………………..
…………………………………………………………………………..

Do you think that you have eaten as you would usually do?
………………………………………………………………………….
………………………………………………………………………….
………………………………………………………………………….

We appreciate your time and efforts in filling out such a detailed diary. Thank you.

For office use

	Wt(kg)	Ht(cm)	Ws (cm)	Hp (cm)	W/H
1					
2					
3					
Av.					

07 March 2005

Figure 3.7 Back cover of food diary

3.3.2. Piloting of the food diary

Piloting of the diary was kept to a minimum as it was adapted from two validated methods used in previous studies (Fletcher *et al*. 2004; Craigie, *et al.* 2004; Lake, *et al*. 2004b). Therefore the primary purpose was training and testing data collection protocols by the author. A number (n=10) of people (HNRC staff and families including subjects in the age-group to be studied) were asked to complete a food diary for a period of three days and to report any feedback e.g. in terms of clarity of both verbal and written instructions.

3.3.3. Delivery and instruction of food diary – visits 1 and 3

Where possible - for example at schools – appointments (vists1 and 3) were made in groups for delivery and instruction in use of the diaries and activity monitors (Chapter 3.4). After confirming that the days of recording their information remained convenient, the date and time arranged for collection and interview were written on the first page of the diary (Chapter 3.3.1) and participants were presented with their diaries.

Participants were advised that the procedure was similar to when they were in middle school and that there was an instruction page on the inside cover of the diary to refresh their memory. They were asked to record the time at which items were consumed and with as much detail as possible (Chapter 3.3.1) *all foods* they had eaten over the 3-days including drinks, snacks and alcohol (Figure 3.5). To improve accuracy of nutritional data, participants were asked to record details of any home cooked recipes at the back of the diary (Chapter 3.3.1) and to retain packaging of foods such as ready meals, for which a university branded plastic carrier bag was supplied. Data were not collected for nutrient supplements (e.g. vitamins, mineral and fish oils) as these do not contribute to total daily energy intake of participants. Participants were however asked to record supplements such as protein drinks, that would contribute to their daily energy intake.

3.3.4. Interview (visits 2 and 4)

On the day following, or at the most two days (to minimise memory lapse) after completion of the food diary, each participant was interviewed about their diary content (visits 2 and 4). Interviews took place on an individual basis and where appointments were held at schools/college or workplace a private room was made available.

The interview was used to ensure all foods eaten over the 3 days had been recorded, and to clarify the data recorded in the diary such as legibility, type of foods, e.g. "Biscuit – chocolate or plain?" time of intake and portion size. Portion sizes were estimated using a photographic food atlas (Nelson, *et al.* 1997) and recorded in the appropriate column in the diary (Figure 3.5). Each page of the food atlas contained eight coded photographs of foods of known weights. Participants were presented with the atlas at the beginning of the interview. They were then asked to identify the portion size of a particular food that was representative of that consumed by the participant at the given time point in their food diary. Weights of the food in the photograph are located in a separate manual that accompanies the atlas, and also in electronic format on a specifically designed database (Chapter 3.3.5). In addition to Nelson, *et al.* (1997) food portion size atlas, food packaging was used to further clarify item weights.

3.3.5. Processing the dietary information

A purpose-built Microsoft Access database was created for the 2000 study and amended for this 2006 study. The database contained participant personal data (ID, and date of birth), food composition tables (Chapter 3.3.4), and forms on which to enter participant dietary data (Chapter 3.3.3).

Classification of eating events

Participants were asked to record the time each food was eaten (Chapter 3.3.3); all foods eaten at one time was referred to as an 'intake'. Each intake was then categorised as either a snack or meal (Fletcher, 2003). "*An' intake', also referred to as 'an eating event', is defined as foods eaten all at one time and that consisted of a few* *code items e.g. 'cornflakes with milk, toast and butter, and a cup of tea' is one intake; 'ham sandwich, crisps and orange squash' would be a second intake. An 'item' is defined as foods eaten within an intake e.g. 'cornflakes with milk' is one item; 'toast and butter' is a second item; and a 'cup of tea with milk' is a third item, all consumed within one intake".* Criteria for defining each eating event as a meal (Fletcher, 2003) were: i) a number of items eaten together, taken over a 15 minute period; ii) Foods making a major contribution(>25%) to that day's energy intake; iii) Foods eaten at recognised mealtimes; or iv) consisting of at least three items. To be classified as a meal an intake had to meet at least 3 of these criteria. All other intakes were defined as snacks, that is, for example a single item consumed (such as an apple); making a less than 25% contribution to days energy intake (such as crisps); eaten outside of meal times as defined for each individual, (for example apple and crisps eaten by an individual at 10.30am where a clear 'breakfast' and 'midday meal' are recorded).

Portion size

From the interview process, participants identified, using the food photographs (Nelson *et al.* 1997), appropriate portion sizes for foods they had consumed (Chapter 3.3.4). The estimated weight of the food, obtained using the separate manual or database (Chapter 3.3.5) which accompanies the photographic food atlas, was recorded in the food diary (Figure 3.5). Standard portion weights were allocated to foods such as eggs, that were not listed in the photographic food atlas, using reference text "Food Portion Sizes" (MAFF, 1999). Various websites, including Tesco.co.uk, Sainsbury's.com, ASDA.com and McDonalds.co.uk, were used to obtain portion size data on items such as confectionery, alcoholic beverages and new products that were not listed in the Food Portion Sizes book (MAFF, 1999).

Coding

All foods were coded using the most recent food composition data for each food from McCance & Widdowson's Composition of foods 6th edition (Food Standards Agency, 2002) and supplements - computerised (Chapter 3.3.5) and text editions:

Cereals and cereal products (Holland *et al.* 1988)

Milk products and eggs (Holland *et al.* 1989)

Vegetables, herbs and spices (Holland *et al.* 1991)

Fruit and nuts (Holland *et al.* 1992a)

Vegetable dishes (Holland *et al.* 1992b)

Fish and fish products (Holland *et al.* 1993)

Miscellaneous foods (Chan *et al.* 1994)

Meat, poultry and game (Chan *et al.* 1995)

Meat products and dishes (Chan *et al.* 1996)

A Microsoft Excel spreadsheet was created of all foods that had a brand name and could be given more than one food code according to their nutritional composition (e.g. Flora). This allowed standardisation of coding i.e. only checking once for comparable nutrition data and using one single code for that product throughout. Where a food did not have an exact match for a specific code, where possible a close alternative was allocated. Where dishes where made up of several components, each component was allocated the relevant food code from the database and the weights were calculated as a proportion of the total product weight. The list of ingredients was obtained either from recipes (Chapter 3.3.3) or from manufacturer's data. In some cases where manufacturer's data were unavailable, foods were dissected and each component was weighed separately for example a 'Greggs sausage and bean melt'.

A record was made of all foods that did not have an appropriate food code listed in the database. These foods were then checked against a 'food-coding wheel' which was created using data from other studies previously conducted in the Human Nutrition

Research Centre. If it was not possible to identify comparable data for these foods, new codes (from a consecutive list (i.e. 21000 series) compiled by other studies at the Human Nutrition Research Centre) and nutrient fields were created in the database, based on manufacturer information. Since nutritional data for alcoholic beverages known as ‘alcopops’ were unavailable from the manufacturers, information from the website http://www.nutracheck.co.uk was used to create food codes with nutritional data for these products. This website provided total energy values only, so data from McCance and Widdowson 6th edition (Food Standards Agency, 2002) were used to calculate energy values from each macronutrient.

Data entry and cleaning

Once all the food diaries were coded, all dietary data were entered into the database and a process of ‘cleaning’ was carried out. This was to highlight any unusual entries such as high values that could be checked against the food diaries and amended if necessary. Some simple checks built into the database ensured errors during entry were minimised. For example food codes were limited to a maximum of five digits. Initially data were verified by means of double entry. Food codes and weights of foods were entered manually into the participant’s diaries and then clarified when entered into the database. These data were then checked using a sample of the data (26%). Data from the first 50 participants were used to form part of an undergraduate dissertation in 2005. The student entered the data for these participants as outlined above and the data were re-entered by the researcher (Alison Hossack). The next step was to check the database as a whole. Methods included sorting the food codes used by frequency to detect any unusual codes or foods with two codes for the same nutritional data. Frequency of food codes used was sorted by weight to search for any unusually high or low weights for particular foods and amended if necessary. Nutritional analysis was then carried out as described in Chapter 3.9.

3.4. Measurement of physical activity

As with dietary intake (Chapter 2.4), measurement of habitual physical activity is notoriously difficult and published literature of reliable methods of measurement in this age group is scarce. Extensive studies using accelerometers have been undertaken previously (Chapter 2.6), but this literature is limited to children, young adolescents and adults. The decision making process and adoption of accelerometers in this study are discussed in the following sections.

3.4.1. Decision about activity measurement

To explore the application of accelerometers in greater detail, a visit was made to the laboratories of Prof. John Reilly (Glasgow) who has considerable experience in studies of activity in children. Information was provided to assist in the type of monitors available for purchase, their application and an indication of the most appropriate methods (literature) of study of adolescents. Fifteen activity monitors were loaned by the team in Glasgow, and a further fifteen monitors were purchased from “Actigraph™”. This purchase included belts, calibrator, data-reader and computer software for all 30 monitors.

3.4.2. Piloting of measurement of physical activity

The Actigraph™ activity monitors were piloted by several volunteers from the HNRC office. Volunteers were asked to wear the monitors for one week during waking hours (see protocol: Appendix 8) and data were downloaded using the Actigraph™ software. To assess the reliability of data, volunteers were interviewed with their data file and asked to verify their level of activity, i.e. were the data recorded an accurate representation of the volunteers’ actual level of activity.

3.4.3. Practical aspects of accelerometry

Prior to use, each monitor was initialised to create a unique data file for each participant using the Actigraph™ software programme (refer to protocol (Appendix 8).

In the pilot study each monitor was set to 15 second intervals (referred to as ‘epochs’) as outlined in Chapter 2.6. However, as indicated by the large sections of ‘0’ counts, it was apparent that young people of this age were far less active than children or younger adolescents. Therefore in the main study each monitor was set to 1 minute epochs (Chapter 2.6). The date and start time was when an appointment was made to meet with the participant to present them with the monitor. ‘Participant ID’ was the unique identification number (Chapter 3.2) required for allocating individual data files. The Actigraph™ software programme was used to stop the monitor recording and to download the data to the individual data files.

3.4.4. Delivery and instruction of accelerometers

Accelerometers were delivered at the same time as each food diary (Visits 1 and 3). Participants were asked to wear the monitor on the left hip underneath clothing, during waking hours from delivery until collection. They were asked to record in the space provided on the food diary, the time period when the monitor was worn, if it was removed the reason why it was removed, e.g. to shower or go to bed. Recording was for a period of 3 days to coincide with dietary data collection (Figure 3.6). Interviews took place on the fourth day to coincide with food diary interviews (Chapter 3.3.4). Participants were asked about their activity over the 3 days e.g. was the monitor worn during sporting activity or for which activity the monitor was removed.

3.4.5. Processing of activity data

Activity data were downloaded automatically into a Microsoft Excel spreadsheet using an Actigraph™ software programme (Chapter 3.4.3). The automated data included the recording time of the monitor i.e. time and date the monitor commenced and the time and date it was stopped (Chapter 3.4.3), and activity data expressed in counts per minute. As outlined in Chapter 3.4.3 the monitors were set to record data from delivery at visits 1/3 to collection at visits 2/4 which in most cases generated data for more than 3d at each phase. These data were then copied into a separate Microsoft Excel file for manipulation. Data (activity counts per minute, start time and date of monitor, and stop time and date of monitor) were defined in the first instance into the three days of data (i.e. those of the dietary data) i.e. data outside the three days recording period (Chapter 3.4.4) were omitted from the file. Data from each of period of collection (T1 and T2) were then combined into one file and each day of data was transposed into a separate worksheet (6 worksheets within one file). A macro file was created to calculate each day's data in terms of hours of recorded data, total minutes of data in each hour, total minutes of data in each day, and mean counts per minute per day. The time spent by participants undertaking light, moderate, hard and very hard activity was calculated by assigning thresholds as defined by Freedson *et al. (*1998). These data were copied to a summary file of activity data of all participants and used in the final analysis.

3.5. Lifestyle questionnaire

A questionnaire was developed to identify lifestyle choices such as smoking and physical activity which may influence diet and health.

3.5.1. Research and Development

The questionnaire was based on previous questionnaires used in a similar study by Lake *et al.* (2004a) and Craigie *et al.* (2004). It consisted of 29 qualitative and quantitative questions (Appendix 9) and was produced in electronic format using Microsoft Word to allow participants to complete on the interviewer's laptop. The questionnaire was divided into five sections presented in the following order: *'About you'; About you and your health; 'About your food choice'; 'About changes in food choice';* and *'About you and your body image'.*

'About you' collected information about the participant including: ethnicity, living circumstances, e.g. alone or with parents or partner, whether they were at school or working, and the occupation of the main earner in their place of residence.

'About you and your health' asked questions about lifestyle from a health perspective, such as whether the participant was a current or past smoker - defined by smoking more than one cigarette on a regular basis (daily or occasionally); their attitude to physical activity, reported levels of physical activity and their perception of their own health.

'About your food choice' investigated participants' food consumption patterns to identify possible influences on choice e.g. where/when/ how often and by whom food was purchased. Influences were further investigated by exploring participants' knowledge of, and attitude to, eating healthily.

'About changes in food choice' sought to identify participants' perceptions of change in their dietary intake since they were 11-12 years old, and what they thought might have influenced these changes.

The final section of the questionnaire*, 'About you and your body image'* explored how participants perceived themselves in terms of shape and size, and their attitude to a healthy body weight. The complete questionnaire is presented in Appendix 9.

3.5.2. Pilot

The pilot questionnaire was emailed to twelve 17 year old high school students from Chester le Street, Co Durham. They were asked to complete the questionnaire and to comment on each question e.g. in terms of understanding. The questionnaire was amended, where appropriate, to incorporate these comments

3.5.3. Delivery and instruction

Participants were presented with the 29 item questionnaire at the end of the second food diary interview (T2, visit 4) (Figure 3.4). Participants were given the laptop to complete the questionnaire and were asked to answer each of the 29 questions honestly. It was explained to them that there were no right or wrong answers and the questions were to provide the researcher with an idea of what might influence food choice in their age group (16-18 years).

3.5.4. Data processing of Questionnaire

A unique questionnaire file was created for each participant on the researcher's laptop, using the participant ID (Chapter 3.2). The answers provided by the participant were recorded directly in a Word document. These data were then coded for analyses using Microsoft Excel. The results of these data are discussed in Chapter 4.

3.5.5. Socioeconomic status

Social class of participants was established in 2000 (Fletcher *et al.* 2004). Occupations of both parents/guardians (where applicable) were classified, and the highest was taken to be the social classification of the participant. These were classified using the 'Simplified Social Class' based on Standard Occupational Classification 1990 (SOC90) (Office of National Statistics, 1990) to allow direct comparisons with the earlier studies in this cross sectional series (Figure 3.1). However, the most recent system SOC2000 (Office of National Statistics, 2000) was also used to allow social comparisons to be made in future studies, such as this follow-up study. Due to a small sample size, for the purpose of analyses, participants were grouped into social groups 'high' (social classes I & II),'middle' (III), 'low' (IV & V) and 'unclassified' (see Chapter 3.2) (Fletcher *et al.* 2004).

3.6. <u>Collection of Anthropometric data</u>

Anthropometric measurements were taken at the end of the study after completion of the questionnaire (T2, visit 4) (Figure 3.4). Height and weight were measured in 2000 and 2006. In 2006, waist and hip circumferences and percent body fat were also measured. Measurement of height and of waist and hip circumference were made in triplicate and the mean of the three measurements was calculated. Bioimpedance analysis (BIA) was used to measure participant weight, BMI, and percent body fat. All measurements were recorded on the back cover of the participants' second (T2) food diary (Figure 3.7). The procedures and devices used for these measurements are described in the following sections. Prior to anthropometric measurement participants were asked to remove their shoes, socks and any outdoor clothing to a single layer (e.g. shirt and trousers), and all Items that would increase the natural weight of the participant such as belts with heavy buckles, mobile telephones, loose change, and wallets.

3.6.1. Height

The height of each participant was measured to the nearest 0.1cm using a portable Soehnle electronic vertical stadiometer. Participants were asked to stand upright with their feet together, knees straight, arms by their side, palms facing inwards and with their head positioned so that the 'Frankfurt plane' was horizontal (indicated by a built-in spirit level on the device).

3.6.2. Waist and hip circumferences

To measure waist circumference, participants were asked to stand with their arms by their side, weight distributed evenly between both legs, breathing normally with their abdomen relaxed. They were then asked to locate their waist by placing their thumb on their lowest rib and at the same time placing their forefinger on the iliac crest. A tape measure was then placed between the thumb and forefinger horizontally around the waist and measurement to the nearest mm was recorded upon expiration.

Hip circumference was measured with participants remaining in the same stance and any items removed from hip pockets. Without indenting the skin, the tape measure was distributed horizontally around the hips over the buttocks at the point of maximum circumference and readings taken to the nearest mm at the side.

3.6.3. Waist : hip circumference ratio (WHR)

Waist and hip circumferences were recorded in the database and WHR was calculated:

$$\text{WHR} = \frac{\text{Mean waist circumference}}{\text{Mean hip circumference}}$$

3.6.4. Percent body fat

Percentage body fat was measured using a Tanita bio-impedance machine as described in the protocol (Appendix 10). The height of the participant, as recorded previously (Chapter 3.6.1) and the age of the participant were entered into the memory of the machine. Participants were asked whether they thought they were athletic, i.e. took part in more than 10 hours of intense physical activity per week (Appendix 10). Their response was then entered into the machine as '*standard Male/Female* 'or *'athletic Male/Female)'*. A printed record of the data (Figure 3.8) which included weight, body mass index (BMI), and percentage body fat, was removed from the machine and attached to the back page of the participant's second food diary (Figure 3.7).

Figure 3.8 Printout of body composition data

3.6.5. Reward for Participation

A voucher to the value of £10 was given on the final interview day to all participants who completed all aspects of the study. That is, they completed two food diaries, had recorded[1] wearing an activity monitor for the same period, completed the questionnaire and had anthropometric measurements taken[2].

Participants who completed all aspects of the study as above, were entered into a draw to win 1 of 5 prizes up to the value of £150. Winners were selected at random by colleagues from the HNRC office. The prizes, which were 'ipod Nano' audio devices, were purchased and delivered to the 5 participants in December 2006.

3.7. Researcher security

Whilst many of the appointments were held at schools, some appointments were at other addresses including participants' homes (Chapter 3.2.1). All appointments were attended by the author alone and therefore it was necessary to have security procedures in place. These included a form which was left with a colleague at the research office or with a member of the researcher's family if after hours. The form included the time of the appointment, the time the appointment was expected to finish, where the appointment was to take place (full address if not at school), and the telephone numbers of the participant and researcher (mobile). The researcher then telephoned the contact person upon arrival and departure from the appointment.

3.8. Validation

To assess the extent to which study findings may be applied outside the research setting two methods of validation were used. The first was to assess how representative (gender, social class, anthropometry and energy intake) the study sample was of the original 2000 sample from which they were derived (Fletcher,*et al*. 2004). The second assessed how representative (anthropometric, nutrient intake and

[1] In some cases when activity monitor data was downloaded it did not correspond with reported data.

[2] Exceptions occurred (see Chapter 3.6.4).

lifestyle) the study sample was of the national UK population (Gregory *et al.* 2000). Data from the present study sample (at age 16-18 years) were compared to the findings of the National Diet and Nutrition Survey (NDNS) (Gregory *et al.* 2000) which is a comprehensive cross-sectional survey of the dietary habits and nutritional status of the population in Great Britain (Chapter 2.3). For comparison, the survey used the weighed intake methodology for dietary assessment and information about physical activity was obtained from a physical activity diary. Anthropometric measurements were taken by trained observers. BMI was calculated and divided into age-sex specific quintiles for analyses. Information on lifestyle behaviour such as smoking was obtained from a questionnaire and interview.

The statistical analysis used in this validation is discussed in Chapter 3.9.

3.8.1. Dietary data

Validation of dietary recording in this study was by comparing recorded energy intake with estimated energy needs based on predicted BMR (Schofield *et al.* 1985b) (Chapter 5).

3.8.2. Physical activity data

Volunteers from the pilot study were shown their data file and asked to verify their levels of activity i.e. were the data recorded an accurate representation of the volunteers' actual level of activity. Further validation of the activity data in this study was by comparing measured activity levels with self reported physical activity. Self reported physical activity was recorded on an electronic questionnaire (Chapter 3.5).

3.8.3. Anthropometric data

A Tanita™ bio-impedance machine was calibrated as new at the beginning of the project and verified at the end of the study using weights from 2kg to 100kg, when accuracy was confirmed and further calibration was not required.

3.9. Calculations and statistical analysis

3.9.1. Dietary analysis

A Microsoft Access database was developed for the 2000 study and was adapted for this follow-up study (Chapter3.3.5). Analysis was limited to those participants with 6 complete days of dietary data.

3.9.2. Test for normality

Many of the analyses used in this thesis are based on the assumption that the data are normally distributed. The distribution of each nutrient was tested using normal probability plots (Q-Q). Observed plots that did not closely follow the normal expected plots were considered to be non-parametric and were transformed to achieve normal distributions. In some cases, alternative non-parametric tests were used, for example Kruskal Wallis tests and Spearman Rank correlations which do not make assumptions about the distribution of the data.

3.9.3. Data description and group comparisons

All data analyses were carried out using SPSS version 15 for Windows; Minitab 14 and STATA version 9. Data were described according to their means and either 95% confidence intervals or standard deviation of the mean (standard error). Comparisons between groups, such as between males and females, were carried out using independent-samples t-tests. Between groups (>2) analysis was tested using the Kruskal-Wallis test which compares the mean rank of a continuous variable (e.g. BMI) in each group (e.g. social group). Comparisons with set values, such as between the BMI of the sample and a national study were carried out using one-sample t-tests. Changes between 11-12 years and 16-18 years were carried out using paired t-tests. All differences were considered significant if *p*-values were <0.05.

3.9.4. Tracking analyses

The tracking of nutrient intake or anthropometry between 11-12 years and 16-18 years was assessed primarily by Pearson correlation analyses, the extent of the tracking being based on both the significance and magnitude of the correlation coefficient. In addition, by dividing the sample into quartiles according to their values at age 11-12 years the values at age 16-18 years could also be compared and the extent to which quartile at age 11-12 years was a predictor for the value at age 16-18 years was assessed by regression analyses. The Kappa (*k)* test were applied to these data to test the magnitude of tracking By chance alone 25% of participants in each quartile would be expected to maintain their position, the Kappa test removes the chance element of this occurrence and a *k* value reveals the strength of agreement (Altman, 1991)

3.9.5. Modelling the prediction of adiposity in young adulthood

General linear modelling (GLM) was used to build models that would predict body size in late adolescence (age 16-18 years) (Chapter 8). GLM can be seen as an extension of multiple linear regression for a single variable, the difference being that GLM can additionally test for categorical predictors. Its purpose is to quantify the relationship between several independent variables, or predictors (e.g. BMI, nutrient intake at age 11-12 years, and nutrient intake at age 16-18 years) and a dependent variable (e.g. BMI at age 16-18 years). This allows for the possibility that more than one predictor may influence the dependent variable and that the overall prediction of BMI at age 16-18 years for example, is improved by taking more than one predictor into account.

The procedure assumes that the data are from a random sample, from a normal population (Chapter 3.9.2) and that all variances are the same. The number of factors tested is limited by the sample size since the higher the number of factors tested, the greater the likelihood of the null hypothesis that there is no association between the factors being rejected when it is in fact true. For example, a sample of 200 would allow a maximum of 10 factors to be tested using a *p*-value of 0.05 as the cut-off. In the present study, the models were built using a step-wise approach and interactions assessed with gender only. The result was a regression equation that make up those factors, which, used together, could be used to statistically significantly predict body size (BMI, % body fat, WC, WHR) at age 16-18 years.

The variables tested as predictors are discussed in Chapter 8 and the remainder of this section outlines the procedure used to build each model:
The first step was to test each variable independently, i.e. as 'one-variable' models. An example of a one-variable model is BMI at age 11-12 years which in this case had a *p*-value of 0.001 and therefore was found to be significantly predictive of BMI at age 16-18 years. The R^2 value for the model was 0.503 indicating that 51% of the variation in BMI at age 16-18 years was explained by BMI at age 11-12 years. All one variable models were tested in the same way and are shown in (Appendix 11). The next step was to add, one at a time, each of the other variables into the most significant one-variable model, which in this case was BMI at age 11-12 years. The variable found to significantly contribute to the model and increase the R^2 value by more than 1% (that is >0.01) was added to the model to form a two-variable model. In this case the two-variable model containing BMI at age 11-12 years and smoking status at age 16-18 years was significantly predictive of BMI at age 16-18 years as evidenced by the significant *p*-value (0.001) and R^2 0.517.

The procedure was then repeated by adding each variable in turn to the most significant two-variable model to form three-variable models. This process continued until no variables added were found to be significant when added to the models. The most predictive model was the model with the largest R^2 value when all variables included were significant. The resulting regression equation could then be derived (Chapter 8) and an example of the output for the model is given in Figure 3.9 and

Figure 3.10. These illustrate the intercept, coefficients (ß) for each predictor and the standard errors of each.

Tests of Between-Subjects Effects

Dependent Variable: LogBMI17

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2.556[a]	8	.320	28.414	.000	.554
Intercept	.442	1	.442	39.342	.000	.177
Employment status	.117	4	.029	2.595	.038	.054
Smoking status	.109	3	.036	3.223	.024	.050
logBMI11	2.071	1	2.071	184.177	.000	.502
Error	2.058	183	.011			
Total	1850.748	192				
Corrected Total	4.615	191				

a. R Squared = .554 (Adjusted R Squared = .534)

Figure 3.9 SPSS output testing employment status (age 16-18), smoking status (age 16-18) and Log BMI at age 11-12 years as predictors of BMI at age 16-18 years.

Parameter Estimates

Dependent Variable: LogBMI17

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	.916	.162	5.667	.000	.597	1.234
Unemployed	.056	.043	1.293	.198	-.029	.141
Work Part time	.063	.051	1.249	.213	-.037	.163
Work full time	.068	.026	2.597	.010	.016	.119
College	.047	.022	2.129	.035	.003	.090
6th Form college	0[a]	.	.	.	.	.
Smoke daily	.026	.024	1.071	.285	-.022	.075
Smoke occassionally	.088	.030	2.911	.004	.028	.148
Used to smoke	.032	.040	.796	.427	-.047	.111
Never smoked	0[a]	.	.	.	.	.
logBMI11	.720	.053	13.571	.000	.615	.825

a. This parameter is set to zero because it is redundant.

Figure 3.10 SPSS output of the regression equation for the prediction of BMI at age 16-18 years from employment status (age 16-18) smoking status (age 16-18) and BMI at age 11-12 years.

4. PARTICIPANT RECRUITMENT AND CHARACTERISTICS

Chapter overview

- Introduction
- 4.1 Location and degree of consent
- 4.2 The study participants
  - 4.2.1 Demographic characteristics
  - 4.2.2 Anthropometric measurements
  - 4.2.3 Lifestyle Characteristics
- 4.3 Association between nutrient intake and adiposity
- 4.4 Association between physical activity and adiposity
- 4.5 Association between nutrient intake and physical activity
- 4.6 Discussion

Introduction

Adolescence, especially middle to late adolescence, is an important period of transition in a person's life as this is a period of rapid growth and development (Chapter 2.2). It is a time when there is inevitably a relatively high demand for energy and nutrients to sustain this rapid growth (Webb, 2002). It is also a time of increased independence and adolescents spend more time away from home as a result of social, school, and community activities and jobs (Wills, 2005). Subsequently, increasingly busier lifestyle is among the most important factors influencing adolescent food choice i.e. the amount of time an adolescent "*has or wants to spend on food*" (Neumark-Sztainer *et al.* 1999).

The aims of this Chapter are: to describe these young people at age 16-18 years including their education/employment, place of residence and living arrangements, providing a snapshot of young people of this age (16-18 years); and to identify some of the demographic characteristics (social group and employment status) and lifestyle behaviours (diet (including alcohol), physical activity and smoking) associated with adiposity in this study population.

In the first instance this Chapter describes the results of tracing (locating and recruiting) these young people to take part in this follow-up study at age 16-18 years. From this point forward, the 424 individuals who took part in the original study in 2000 when aged 11-12 years (Chapter 3.1) are referred to as '*respondents*' and the individuals who took part in this follow-up study are referred to as '*participants*' from this point forward.

4.1. Location and degree of consent

Information was obtained from the 7 middle schools (Chapter 3) regarding which High school respondents had moved on to. It was apparent that there were four *main* High schools (Table 4.1), all of which are in Northumberland, namely *King Edward VI School*, Morpeth, *St Benet Biscop Catholic High School*, Bedlington, *Ashington Community High School and Sports College* and *Hirst High School Technology College*, both of which were in Ashington. A breakdown of the number of respondents remaining at each school (sixth form) is shown in Table 4.1. 211 respondents were located to these high schools and 2 respondents had died (213). The remaining young people who were not at these four high schools (n=211) were sought via "Connexions, Northumberland[1]" (Chapter 3) or via staff and students at the high schools.

Connexions had contact addresses for 142 (67%) of these 211 respondents, of whom 58 did not respond and were sought via other sources as described (Chapter 3.1.2). Thus with the assistance of Connexions, school staff and students, an additional 134 respondents were traced to other schools, colleges or place of work. Of the original cohort (n=424) 77 respondents (18%) remained untraced for the duration of this follow-up study (Table 4.1).

[1] NB: Connexions Northumberland is a confidential advice and support service for young people aged 13 to 19 years (www.connexions-tw.co.uk)

Table 4.1 Location and recruitment of respondents

Location	Respondents	Consent	Completed study (n)	Dropped out T2 (n)	Non-consent	No response
King Edward VI School	116	84	79	5	30	2
Ashington High School	25	18	16	2	5	2
Hirst High School	46	36	29	7	7	3
St Benet Biscop RC High School	24	13	13	0	10	1
Other School/College/Work	134	73	56	17	32	29
Untraced	77	-	-	-	-	-
Deceased	2	-	-	-	-	-
Total	**424**	**224**	**193**[2]	**31**	**84**	**37**

Of the respondents (n=345; 81% of original cohort) who were contacted, 84 did not consent to take part and 37 did not respond (Table 4.1). The total number of respondents from whom consent was received was n=224 (52%), of whom n=31 were lost to follow-up at T2. A total of n=193 (45% of original cohort) participants completed all aspects[3] of this follow-up study. It is important to note, that this figure (193) includes one female who suffered from scoliosis, an impairment of the spine affecting the height and this participant was omitted from all anthropometric analyses. The remaining figure of 192 included two female participants who were pregnant and provided self-report weight & BMI (from doctor); a further two female participants had a plaster cast on one of their legs which precluded bio-impedance analysis. However height and weight of these two participants were measured, taking into account the weight of the plaster cast, and BMI was calculated (weight (kg) / height (m^2))(Chapter 3.6). These four

[2] Completed all aspects of the study: dietary data; physical activity data; anthropometric data and questionnaire (Chapter 3).

[3] Completed all aspects of the study: dietary data; physical activity data; anthropometric data and questionnaire (Chapter 3).

participants have been accounted for in anthropometric analyses which is reflected in the tabulated data (Table 4.4).

On the whole reasons for non-participation in this follow-up study or for 'dropping out' at T2 were not obtained, however, where asked, the general response was 'they were too busy' or 'not interested'. One person is known to have moved out of the country after the initial study in 2000 and three participants were reported to be away in the army during this follow-up study period. On the whole, the other people who were untraced remained so as they did not respond to the methods adopted for tracing them (Chapter 3.1)

<u>Summary of Chapter 4.1</u>

- 81% of the original cohort were contacted, 11% of which did not respond
- 50% of the original participants of the 2000 cohort were traced to four high schools in Northumberland: *King Edward VI School*, Morpeth, *St Benet Biscop Catholic High School*, Bedlington and *Ashington Community High School and Sports College* and *Hirst High School Technology College*, both of which were in Ashington. 65% of these participants completed all aspects of the study.
- Of the remaining 50%, 26% completed all aspects of the study, 2 participants were deceased and 36% were untraced.
- Consent was received from 52% of the original cohort to take part in this follow-up study.
- 45% of the original cohort completed all aspects of this follow-up study.

4.2. <u>The study participants</u>

This section describes the demographic, anthropometric, and lifestyle characteristics of participants at age 16-18 years. For reference, how these data compare with that of the original study are discussed in Chapter 5.

The mean age of participants at T2 (visit 4 (Figure 3.4)) was 17.6 years. All but two (1 White & Black African and 1 Indian) of the participants were classified as White British. None of the participants lived alone and the majority lived at home with parent(s)/guardian(s) (95%), or grandparent(s) (3%); only 2% (n=3) of participants had moved out and lived with a partner; one participant had a child (not living with participant) and two were pregnant during the data collection period. In this follow-up study there were more female participants (65%) than male participants (35%) subsequently all analyses were stratified by gender.

4.2.1. Demographic characteristics

Social class was established in 2000 using head of household occupation. All reported data at age 11-12 years were analysed using the 'simplified social class' method (SOC 1990) (Office of National Statistics, 1990), and, for continuity, this is the method used in all analyses reported herein. Due to the relatively small sample size, for the purpose of analyses, participants were grouped into 4 social groups 'high' (social classes I & II),'middle' (III), 'low' (IV & V) and 'unclassified' (Fletcher, *et al*. 2004) (Chapter 3.2).

There were high proportions of participants from the 'high' (56%) and 'middle' (25%) social groups compared with those of the low and unclassified social group (12% & 6%). In all social groups the proportions of male and female participants were similar (Table 4.2).

Table 4.2 Social group of participants (based on parental occupation in 2000)

Social group	Males (%)	Females (%)	Total (%)
n=	67	126	193
High (I & II)	39 (58)	69 (55)	108 (56)
Middle (III)	17 (25)	32 (25)	49 (25)
Low (IV & V)	9 (13)	15 (12)	24 (12)
Unclassified (VI)	2 (3)	10 (8)	12 (6)

In terms of primary occupation of participants, most participants (83% (73% male; 89% female)) remained in education at age 16-18 years (some participants also worked part-time whilst at college). Females were more likely than males to be in full time college education (6% male; 23% female). Males were more likely than females to be working full time (19% male; 6% female) or be unemployed (8% male; 2% female) and only females (4%) reported working part time as their primary occupation (Table 4.3).

Table 4.3 Employment characteristics of participants

Employment status (primary occupation)	Male (%)	Female (%)	Total (%)
n=	67	126	193
School Sixth Form	45 (67)	83 (66)	128 (66)
College	4 (6)	29 (23)	33 (17)
Working full time	13 (19)	7 (6)	20 (10)
Working part time	0	5 (4)	5 (3)
Unemployed	5 (8)	2 (2)	7 (4)

4.2.2. Anthropometric measurements

Anthropometric measurements of participants, that is weight, height, body mass index (BMI), percent body fat (BIA), waist circumference, hip circumference and waist to hip ratio (WHR) are presented in Table 4.4. All anthropometric measurements were found to be non-parametrically distributed and were subsequently $\log_e$ transformed to create normally distributed datasets before analyses. The means shown are the $\log_e$ means back transformed into the original unit means (geometric means).

As stated in Chapter 4.1 one participant suffered from scoliosis, an impairment of the spine affecting the height and this participant was omitted from all anthropometric analyses. Therefore the number of female participants for whom height, weight and BMI was recorded is 125 (Table 4.4). Two participants were pregnant at the time of measurement and did not have anthropometric measurements taken; however their height, weight were self-reported and therefore included in the analyses. A further two female participants had a plaster cast on one of their legs which precluded bio-impedance analysis. However height and weight were measured, taking into account the weight of the plaster cast, and BMI was calculated (weight (kg) / height (m^2)). Thus BIA data is recorded for 121 female participants and 123 female participants for waist circumference, hip circumference and WHR (Table 4.4).

On average, male participants were taller and heavier than female participants (Table 4.4). Adiposity at age 16-18 years was assessed using BMI (weight (kg)/height (m^2)), bio-impedance analysis (BIA), waist circumference, waist to hip ratio (WHR) (Table 4.4). The mean BMI of all participants was 22.3 (22.1 females; 22.4 males). As expected (Chapter 2.2.1), females had a greater mean percentage of body fat (24%) than males (12%) (Table 4.4). Figure 4.1 illustrates the distinct gender difference and significant correlations (r=0.86 males; r=0.91 females; both $p<0.01$) between BMI at age 16-18 years and measured percent body fat (BIA) at age16-18 years.

A Kruskal Wallis test revealed little effect of social group on BMI and % body fat in females (p=0.89, p=0.76 respectively). However, males in the higher social group had a lower mean BMI (p<0.05) (Chapter 6) and lower mean % body fat (p<0.05).

To analyse the anthropometric data from a health perspective, participants were classified as 'normal', 'overweight' or 'obese' using age and sex specific cut-offs[4] for BMI as described by Cole *et al.* (2000); and as 'normal', 'overfat' or 'obese' according to % body fat (BIA) as defined by (McCarthy, Cole *et al*. 2006). Using BMI as an indicator of overall body fatness, Table 4.5 shows that the prevalence of overweight or obese in this sample was 24% (20% females; 31% males). This compares with 16% (19% females; 12% males) overfat or obese when BIA is the method of assessment (Table 4.6).

Further assessment (Table 4.4) of the distribution of body fat revealed that, as would be expected (Chapter 2), on average females had a lower mean waist circumference (76cm) compared to that of males (82cm). Similarly the mean waist to hip ratio of females (0.77) was smaller than that of males (0.83). Figure 4.2 illustrates that around 80% of both males and females who were in the highest quartile for BMI at age 16-18 years were also in the highest quartile for waist circumference at age 16-18 years. Applying estimates of risk factors for cardiovascular disease and diabetes from abdominal fatness in adults (Lean *et al*. 1995) females were at greatest risk (data not illustrated). 23% of females in the third quartile were at increased risk (WC≥80cm), compared with 6% of males (WC ≥94cm) in the same quartile. In the highest quartile of BMI, 45% of females compared with 41% of males were at increased risk according to their WC (≥80cm & ≥94cm respectively). In the same quartile none of the males were identified as being at high risk (>102cm) compared with 42% of females (>88cm).

[4] International BMI cut offs for overweight age 17.5 years = 24.73 (Male); 24.85 (Female)
International BMI cut offs for obesity age 17.5 years = 29.70 (Male); 29.80 (Female)

Table 4.4 Anthropometric characteristics of participants

Characteristic	Male			Female		
	No.	Mean	Range	No.	Mean	Range
Height (m)	67	1.78	1.62 - 1.95	125	1.63	1.32 - 1.79
Weight (kg)	67	70.9	46.8 – 108	125	59.0	35.9 – 100
BMI (kg/m2)	67	22.4	16.2 - 30.0	125	22.1	16.4 - 36.9
% Body fat	67	12.1	1.30 - 24.7	121	24.2	4.50 - 43.3
Waist circumference (WC) (cm)	67	81.8	70 0- 100	123	75.5	62.0 – 110
Hip Circumference (HC) (cm)	67	98.9	89 0- 115	123	98.3	84.0 – 122
Waist to hip ratio (WHR)	67	0.83	0.74 - 0.95	123	0.77	0.66 - 0.92

Table 4.5 Prevalence of overweight and obese assessed using BMI[5] of participants at age 16-18 years

Gender	BMI classification at age 16-18 years			
	No.	Normal (%)	Overweight (%)	Obese (%)
Male	67	46 (69)	20 (30)	1 (1)
Female	121*	97 (80)	19 (15)	5 (5)
All participants	188	143 (76)	39 (20)	6 (4)

*** Females n=121 as complete BMI and BIA data unavailable for 4 females (Chapter 4.2.2)**

Table 4.6 Prevalence of 'overfat' and 'obese' as assessed using percent body fat [6]of participants at age 16-18 years

Gender	% body fat classification at age 16-18 years			
	No.	Normal (%)	Overfat (%)	Obese (%)
Male	67	59 (88)	6 (9)	2 (3)
Female	121*	98 (81)	6 (5)	17 (14)
All participants	188	157 (84)	12 (6)	19 (10)

*** Females n=121 as complete BMI and BIA data unavailable for 4 females (Chapter 4.2.2)**

[5] International BMI cut offs for overweight age 17.5 years = 24.73 (Male); 24.85 (Female)
International BMI cut offs for obesity age 17.5 years = 29.70 (Male); 29.80 (Female)
[6] Body fat reference curves;
Overfat age 17years 20.1% (male) 30.4% (female); age 18years 20.1% (male) 30.8% (female)
Obese age 17years 23.9% (male) 34.4% (female); age 18years 23.6% (male) 34.8% (female)

5. REPRESENTATIVENESS OF THE DATA

Chapter overview

- Introduction
- 5.1 Characteristics of respondents at age 11-12 years to determine how representative this follow-up sample were of the original 2000 cohort
    - 5.1.1 Gender
    - 5.1.2 Social group
    - 5.1.3 Anthropometry
    - 5.1.4 Nutrient intake
- 5.2 Comparisons between characteristics of this follow-up study sample and a national study of young people aged 15 to 18 years
    - 5.2.1 Lifestyle and demographics
    - 5.2.2 Anthropometry
    - 5.2.3 Energy and macronutrient intake
- 5.3 Validity of the dietary data
- 5.4 Discussion

Introduction

In any epidemiological study, it is important to understand the potential transferability of the data and so the findings derived. In the context of the population from which the study sample are drawn, how representative are the data and do the findings reflect the behaviours of a select group, that is young people in a particular area of North East of England, or can these findings be generalised to a wider UK population of the same age.

When choosing a method for collecting food intake data (Chapter 2.4) in adolescents the principal aim was to collect intake data which were representative of *usual* or *habitual* intake (Torun *et al*. 1996; Nelson, 2000b). Two main factors are important to consider when comparing dietary assessment methods: validity (or accuracy) and reliability (Chapter 2.4).

The aims of this Chapter are:

1. To identify how representative the data of the present study were of the original study sample in 2000. The characteristics (gender, social class, anthropometric measurement and dietary intake) of respondents (follow-up participants and non-participants) at age 11-12 years were compared with the whole 2000 sample (Chapter 5.1);
2. To determine the extent to which the findings of this study may be applied to the wider population by comparing the data of present study participants (age 16-18 years) with data from the most recent UK study of young people i.e. the National Diet and Nutrition Survey (NDNS) of 4-18 year olds (Gregory *et al.* 2000) (Chapter 5.2) and;
3. To assess the likely validity of measured intake and to identify possible under and over-reported dietary data, thereby establishing how representative the collected data were of usual or habitual behaviour.

5.1. Characteristics of respondents at age 11-12 years to determine how representative this follow-up sample were of the original 2000 cohort.

The characteristics of respondents (follow-up participants and non-participants) at age 11-12 years compared with the whole 2000 sample are illustrated in Table 5.1 to Table 5.5. The variables considered are gender, social class, anthropometric measurement and dietary intake.

5.1.1. Gender

In the 2000 study there were fewer males (46%) than females (54%). This was also the case in this follow-up study however the difference was greater with the sample consisting of 35% males and 65% females (Table 5.1) suggesting that participation was influenced by gender. For this reason all analyses have been stratified by gender.

Table 5.1 Distribution of participants in the original study and at follow-up by gender

	Participants n (%)	Non-participants n (%)	Total 2000 study sample n (%)
Male	67 (35)	128 (55)	195 (46)
Female	126 (65)	103 (45)	229 (54)

5.1.2. Social Group

Comparisons between participants and non-participants in terms of social group are based on the social classification of participants in 2000 (Chapter 3.5.5). Occupations of both parents/guardians (where applicable) were classified, and the highest was taken to be the social classification of the participant. These were classified using the two methods: the ‘simplified social class’ method based on the standard occupational classification (SOC) of 1990 (Office of National Statistics, 1990) and the most recent system SOC2000 (Office of National Statistics, 2000). However all reported data at age 11-12 years were analysed using the ‘simplified social class’ method (SOC 1990) and is therefore the method used in all analyses reported herein. For the purpose of analyses, participants were grouped into social groups ‘high’ (social classes I & II),’middle’ (III), ‘low’ (IV & V) and ‘unclassified’ (VI, VII & VIII) (Chapter 3.2) (Fletcher *et al.* 2004).

A Chi-Square test was used to compare the social distribution of participants at follow-up with non-participants. There were significant differences between participants and non-participants in both males (p<0.05) and females (p<0.01). The greatest proportion of participants in 2000 were from the high social group at age 11-12 years (47%) (49% males, 45% females) and the same observation is evident in this follow up study (56%) (58% males, 55% females) (Table 5.2). The proportion of participants from the middle social group was similar in 2000 (28%) and 2006 (25%). There was a slight increase (+1%) in the proportion of males from the low social group whilst the proportion of females from the same group decreased (-4%). Both males (90%) and females (62%) from the unclassified social groups were less likely to take part in this follow-up study

(Table 5.2). These findings suggest that whilst the proportion of participants from the unclassified social group were clearly not representative of the original study in 2000, on the whole the social group distribution of participants were broadly representative of the original cohort.

Table 5.2 Social group distribution of study participants at follow-up (2006) compared with social group distribution of study participants in 2000.

Social group	2000 study participants % (n)			2006 study participants % (n)		
	Male (n=195)	Female (n=229)	Total at age 11-12 years (n=424)	Male (n=67)	Female (n=125)	Total at age 16-18 years (n=193)
High (I, II)	49 (96)	45 (104)	47 (200)	58 (39)	55 (69)	56 (108)
Middle (III)	28 (55)	27 (62)	28 (117)	25 (17)	25 (32)	25 (49)
Low (IV, V)	12 (23)	16 (37)	14 (60)	13 (9)	12 (15)	12 (24)
Unclassified (VI, VII, III)	11 (21)	11 (26)	11 (47)	3 (2)	8 (10)	6 (12)

5.1.3. Anthropometry

Anthropometric measurements analysed in this chapter include weight, height, and BMI at 11-12 years of age (Table 5.2). Weight and BMI were not normally distributed and data sets were log transformed to return the distribution to normality. The geometric (back-transformed) means of all measurements between participants and non-participants are compared. Independent samples t-tests revealed there were no significant differences between participants and non-participants in height (p = 0.91 males, p = 0.71 females), weight (p = 0.61 males, p = 0.12 females) or BMI (p = 0.54 males; p = 0.08 females) for males and females. However female non-participants were on average 2.3kg heavier than female participants when aged 11-12 years.

Table 5. 3 Comparison of anthropometric measurements at age 11-12 years between participants and non-participants in this follow-up study.

	Male (mean)			**Female (mean)**		
	Participant	Non-participant	*p*-value	Participant	Non-participant	*p*-value
Height (m)	1.51	1.51	0.91	1.52	1.53	0.71
Weight (kg)	45.8	45.2	0.61	45.6	47.9	0.12
BMI (kg/m^2)	19.8	19.6	0.54	19.6	20.5	0.08

Using International Obesity Task Force BMI cut-offs[f] (Cole *et al.* 2000) participants were classified as normal, overweight or obese at age 11-12 years. Of the 193 subjects who took part in this follow-up study, 29% (28% males, 29% females) were overweight or obese at age 11-12 years. This compares with 30 % (27% males; 32% females) of the 424 subjects in the original cohort (Table 5.4) and therefore participants in this follow-up study are highly representative of the original cohort. Nevertheless participants who were obese at age 11-12 years (n=29) were less likely to take part in this follow-up study (n=22). Chi-square tests revealed there was a significant (p<0.05) difference between BMI (category) of female participants and non-participants but not between male participants and non-participants.

[f] International BMI cut offs for overweight age 11.5 years = 20.89 (Male); 21.20 (Female)
International BMI cut offs for obesity age 11.5 years = 25.58 (Male); 26.05 (Female)
International BMI cut offs for overweight age 17.5 years = 24.73 (Male); 24.85 (Female)
International BMI cut offs for obesity age 17.5 years = 29.70 (Male); 29.80 (Female)

Table 5.4 Comparison of BMI category at age 11-12 years between participants and non-participants in this follow-up study.

BMI category*ƒ* at age 11-12 years		**Normal % (n)**	**Overweight % (n)**	**Obese % (n)**
All sample (n=424)	Male (n=195)	72 (141)	20 (39)	7 (15)
	Female (n=229)	67 (155)	26 (60)	6 (14)
Participants (n=192)	Male (n=67)	72 (48)	22 (15)	6 (4)
	Female (n=125)	**71 (89)***	**27 (34)***	**2 (3)***
Non-participants (n=231)	Male (n=128)	73 (93)	19 (24)	9 (11)
	Female (n=103)	**64 (66)***	**25 (26)***	**11 (11)***

***Significant difference between BMI (category) of female participants (p<0.05)**

5.1.4. Nutrient intake

Nutrient intakes of participants and non-participants are compared in Table 5.5. Alcohol was consumed by some participants at age 11-12 years, but the number (n=11) and amounts were so small it was not considered further in this analysis. There were no significant differences between participants and non-participants for either males or females (both $p > 0.05$) in respect of total energy intake or contributions made by the major macronutrients to energy intake at age 11-12 years. Thus, in terms of reported energy and macronutrient intake (%EI) at age 11-12 years the follow-up sample was highly representative of the original study sample.

Table 5.5 Comparisons in nutrient data at age 11-12 years between participants and non-participants at follow-up

	Male			Female		
	Participants (n=67)	Non-participants (n=128)	*P* value	Participants (n=125)	Non-participants (n=103)	*P* value
Total EI (MJ/day)	8.4	8.5	0.79	7.7	7.5	0.40
Fat (% energy)	34.2	34.5	0.60	35.2	35.3	0.79
CHO (% energy)	52.6	52.6	0.91	52.6	52.4	0.62
Protein (% energy)	12.7	12.6	0.73	12.0	12.1	0.74

Summary of Chapter 5.1

- Males were less likely than females to participate in the follow-up study.
- Female participants from the lower social groups were less likely to take part in this follow-up study.
- Female non-participants were on average 2.3kg heavier than female participants but there was no difference in BMI.
- The percentage of all participants in this follow-up study who were overweight or obese at age 11-12 years (29%) was representative of the original cohort (30%). However both male (ns) and female (p<0.05) participants who were obese at age 11-12 years were less likely to take part in this follow-up study.
- Mean intakes of energy and macronutrients (%EI) at age 11-12 years of participants of this follow-up study were not significantly different from those of the original cohort.

5.2. Comparisons between characteristics of this follow-up study sample and a national study of young people aged 15 to 18 years

The previous section illustrates how representative this sample was of the original cohort. To establish how representative this study of young people was of the wider UK population, characteristics (lifestyle, anthropometric and nutrient intake) of study participants were compared with data from the most recent UK study (conducted in 1997) of young people i.e. the National Diet and Nutrition Survey (NDNS) of 4 to18 year olds (2000) (Gregory *et al*. 2000). Mean values for each of the variables were compared with the mean values of the sub sample (age 15 to 18 years) NDNS data using one sample t-tests.

5.2.1. Lifestyle and demographics

Whilst social group in both the present study and in the NDNS were derived from parental occupation, comparisons were not possible due to the different methods of classification. For example, the standard occupational classification (SOC) of 1990 (Office of National Statistics, 1990) was used in the present study whereas the NDNS study were classified using a previous system (Registrar General, 1980).

Table 5.6 summarises the main educational status of participants of the present study compared with subjects in the NDNS study.

In both studies, full time education was the most common status during the period of data collection. However a higher proportion of the present study (83%) was in full time education compared with 75% of the NDNS. In the present study, males (19%) were more likely than females (10%) to be working, whilst there was little difference between sexes in the NDNS sample (21% males; 20% females). Fewer females in the present study (12%) had left full time education than females in the NDNS (25%).

Table 5.6 Educational/employment status of present study participants compared with those in the NDNS study.

Location	Sixth Form/college		Work		Other*	
	Present study participants (%)	NDNS (%)	Present study participants (%)	NDNS (%)	Present study participants (%)	NDNS (%)
Male	72	75	19	21	8	4
Female	89	74	10	20	2	5

***Unemployed or economically inactive**

The proportion of participants (34%) in the present study who reported that they had ever smoked was much less than the 15 to 18 year olds of the NDNS study (69%). In the present study, 22% of females and 16% of males (20% total sample) reported that they were current smokers (Chapter 4.2.3), compared with 35% of females and 31% of males in the NDNS study.

5.2.2. Anthropometry

Descriptive data are presented in Table 5.7 by study, and by gender. For all measurements there were no significant differences between male participants in the present study and males that participated in the NDNS survey (Gregory *et al.* 2000). In contrast female participants in the present study had a higher waist circumference (2.4cm; $p<0.05$) and subsequent higher waist to hip ratio (0.02; $p<0.001$) than those in the NDNS study.

Table 5.7 Anthropometric measurements of participants compared with the subgroup age 15 to 18 years olds of the National Diet and Nutrition Survey

		Study participants (mean)	NDNS (mean)	Difference (study participants – NDNS)		
				Mean difference	CI Low	CI Upper
Height (cm)	Male	178	177	0.01	-0.01	0.03
	Female	164	164	0.00	-0.02	0.01
Weight (kg)	Male	72.0	71.0	1.00	-2.02	4.01
	Female	60.0	61.0	-1.12	-3.26	1.02
BMI (kg/m^2)	Male	22.4	22.5	-0.19	-0.64	1.03
	Female	22.4	23.0	-0.61	-1.28	0.05
Waist circumference (cm)	Male	82.2	82.0	0.18	-1.84	2.20
	Female	76.4	74.0	**2.40***	0.59	4.18
Hip Circumference (cm)	Male	99.0	99.5	-0.44	-1.95	1.07
	Female	98.5	99.5	-1.02	-2.41	0.37
Waist hip ratio	Male	0.83	0.83	0.00	-0.02	0.01
	Female	0.77	0.75	**0.02****	0.01	0.03

$*p<0.05$, $**P<0.001$

Using International Obesity Task Force BMI cut-offs[f] (Cole *et al.* 2000) the prevalence of overweight and obesity in this present study was compared (Table 5.8) with the prevalence in those aged 15-17 years in the NDNS study (Jebb *et al.* 2004). In both studies, the prevalence of overweight, or overweight and obese was higher in males than in females. The prevalence of overweight or overweight and obese was very similar in both studies (15% and 15%; 20% and 20% respectively) for females. However for males there was a higher prevalence of overweight and/or obesity in the

[f] International BMI cut offs for overweight age 11.5 years = 20.89 (Male); 21.20 (Female)
International BMI cut offs for obesity age 11.5 years = 25.58 (Male); 26.05 (Female)
International BMI cut offs for overweight age 17.5 years = 24.73 (Male); 24.85 (Female)
International BMI cut offs for obesity age 17.5 years = 29.70 (Male); 29.80 (Female)

present study (30% overweight; 31% overweight and obese) compared with the NDNS study (20% overweight; 24% overweight and obese).

Table 5.8 Prevalence of overweight or overweight/obese among participants in the present study and in the NDNS study.

	Overweight		Overweight/Obese	
	Study participants % (n)	NDNS % (n)	Study participants % (n)	NDNS % (n)
Males	30 (20)	20 (32)	31 (21)	24 (39)
Females	15 (19)	15 (25)	20 (25)	20 (33)

5.2.3. Energy and macronutrient intake

Table 5.9 provides a summary of the mean energy and macronutrient intakes of participants in this study and those in the NDNS study (Gregory *et al.* 2000). Protein intakes were not normally distributed for all modes of expression (%EI, g/d, g/kg/d) and carbohydrate intake (g/d) was also not normally distributed. A log transformation was applied to return these data to normality and the geometric means are compared.

Food energy intakes were higher in males than females in both studies. Energy intakes were significantly higher for both sexes (p<0.001) in the present study by 2.9MJ/d for males and by 2.6MJ/d females. Whilst % energy derived from carbohydrate was significantly (p<0.001) higher in the NDNS study (5.2% points, males; 1.9% points, females), absolute intake (g/d) of carbohydrate was significantly higher in the present study (p<0.001) for both males (36.6g/d) and females (57.9g/d). There was a similar finding for intakes of fat. When expressed as percentage of total energy intake, fat intakes were significantly higher (p<0.05 males; p<0.001 females) in the NDNS study and when expressed as g/d, intakes were lower in the NDNS study (p<0.001). Protein intake by male participants of the present study was significantly higher when expressed as both percent energy (%EI) and g/d (p<0.05 and p<0.001 respectively). As with the other macronutrients, female intakes of protein (g/d) were higher (p<0.001) in the present study whilst percent energy from protein (%EI) was higher, though not significantly so, in NDNS females.

A higher percentage (68%) of participants (60% males; 72% females) in the present study reported consuming alcohol during the recording period compared with 43% (45% males; 41% females) in the NDNS study. When intakes of ‘consumers only’ were compared as % energy from alcohol, there was no significant difference between the present study and the NDNS study. However, when intakes were expressed as g/d, once again intakes were significantly higher in the present study than in the NDNS study for both males and females (p<0.001).

Table 5.9 Energy and macronutrient intake of present study participants compared with those of the 15 – 18 year old subjects in the NDNS study

				Difference (Study participants - NDNS)		
		Present study participants (mean)	NDNS (mean)	Mean Difference	Lower CI	Upper CI
Energy (MJ) /day	Male	12.5	9.60	**2.90****	2.10	3.60
	Female	9.40	6.80	**2.60****	2.10	3.10
Average daily total carbohydrate intake (g)	Male	338	301	**36.6****	25.2	75.1
	Female	272	214	**57.9****	55.1	86.8
Carbohydrate (% energy)	Male	45.3	49.3	**-4.00****	-7.10	-3.30
	Female	48.7	49.7	**-1.00****	-2.90	-0.80
Average daily total fat intake (g)	Male	113	89.0	**23.7****	15.5	31.9
	Female	83.8	64.0	**19.8****	14.2	25.3
Fat (% energy)	Male	33.6	35.1	**-1.50***	-3.80	-0.90
	Female	32.7	35.2	**-2.50****	-4.40	-2.10
Average daily protein intake (g)	Male	105	76.5	**28.2****	22.8	49.9
	Female	68.4	54.8	**13.6****	13.1	20.9
Protein (% energy)	Male	14.7	13.6	**1.10***	0.20	2.30
	Female	12.9	13.6	-0.70	-1.20	0.04
Average daily alcohol intake (g) (total sample)	Male	26.7	6.80	**19.9****	10.6	29.2
	Female	17.9	3.40	**14.5****	10.3	18.6
Average daily alcohol intake (g) (consumers only)	Male	44.1	15.6	**28.5****	0.50	2.40
	Female	24.5	9.30	**15.2****	1.00	2.40
Alcohol (% energy) (total sample)	Male	3.50	1.90	**1.60***	15.6	41.3
	Female	3.10	1.40	**1.70****	10.2	20.3
Alcohol (% energy) (consumers only)	Male	5.80	4.50	1.30	-0.20	2.80
	Female	4.30	3.80	0.50	-0.30	1.30

***p<0.05, **P<0.001**

Summary of Chapter 5.2

- In terms of adiposity both males and females of the present study were representative of the national population in terms of their average BMI, but the prevalence of overweight or obese males was higher in the present study. Waist circumference and waist to hip ratio of female present study participants were significantly (p<0.05 and p<0.001 respectively) higher than in the NDNS study.
- Nutrient intake was not representative of the national population when compared with the NDNS data for this age group (Gregory *et al.* 2000). Energy intake (MJ/d), carbohydrate, fat and protein intake (g/d) were significantly (p<0.001) higher in the present study participants. %EI derived from carbohydrate and fat were lower in present study participants, probably explained by the higher %EI derived from protein and alcohol. Prevalence of alcohol consumption was greater in the present study with 68% (60% males, 72% females) compared with 43% (45% males, 41% females) in the NDNS study. Mean alcohol consumed (g/d) was significantly (p<0.001) higher in present study participants.
- Both males and females of the present study were less likely to be current smokers than in the NDNS data collected 9 years previously.
- In terms of primary education/employment males in the present study were representative of the NDNS. Females however were less likely than those of the NDNS to have left full time education at this age.

5.3. Validity of the dietary data

When choosing a method for collecting food intake data in children and adolescents the principal aim was to collect intake data which were representative of *usual* or *habitual* intake (Torun *et al*. 1996; Nelson, 2000b). However error in measurement of dietary intake has been widely recognised. Under-reporting of dietary intake is a common source of error in epidemiological studies (Nelson, 2000b). The aim of this section is to assess the likely validity of measured intake and to identify possible under and over-reported dietary data. The latter were identified as individuals whose reported energy intake was below that required for basal metabolic rate (BMR) plus the likely level of energy expenditure necessary to carry out daily activities (Livingstone *et al.*1990).

Energy needs are determined largely by BMR with additional requirements for energy expenditure from physical activity, and in the case of children, additional requirements for growth. In the absence of direct measures, BMR can be estimated using the age and sex appropriate equations of Schofield *et al.* (1985b). A person whose energy intake equals their energy expenditure is said to be in ‘energy balance’. Assuming energy balance, estimates of energy requirements could be based on measurements of either energy intake or energy expenditure. Measurements of energy intake are less reliable than direct measurements of energy expenditure and validation studies have demonstrated that a bias in dietary reporting is highly probable (Torun *et al.* 1996). For this reason, estimates of energy requirements are usually based on measurements of energy expenditure. Total energy requirements can be expressed as a multiple of BMR (Torun *et al.* 1996). This is a factor referred to as the *physical activity level* (PAL) and is calculated as the ratio of measured total energy expenditure (TEE) to BMR.

Torun *et al.* (1996) defined lower and upper cut-off points as 1.39 and 2.24 x BMR for males and 1.30 and 2.10 x BMR for females as reasonable estimates of energy requirements of children and adolescents aged 6 to 18 years.

To identify participants in the present study who have reported EIs that may not have reflected *usua*l or *habitual* intakes at age 11-12 years and 16-18 years, reported energy intake was expressed as a ratio of estimated BMR[1]. A ratio of 1.0 indicates that a person has reported consuming the minimum energy requirement for the body to function at rest. If usual or habitual dietary intake is reported it would be expected that EI would be broadly equivalent to energy expenditure (EE), assuming energy balance. Therefore the dietary intake of the participants in the present study was validated by applying the age and sex specific cut-off points defined by Torun *et al.* (1996) to intake data at ages 11-12 years and 16-18 years (Figure 5.1).

Table 5.10 shows the mean reported energy intakes (EI) of participants at age 11-12 years and 16-18 years, together with the mean estimated BMRs[1] (Schofield *et al* 1985b) and calculated total energy intake (EI) to BMR ratio (EI:BMR) for males and females separately. At age 11-12 years reported average energy consumption (1.39 x BMR males; 1.30 x BMR females) was equivalent to the cut-off point for 'low energy reporting' defined by Torun *et al.* (1996). At age 16-18 years this had increased to 1.65 x BMR in males and 1.60 x BMR in females, indicating that at this age, as a group the reported EI's were likely to reflect the usual intake of participants.

Table 5.10 Mean energy intake (EI); estimated basal metabolic rate (BMR) and EI:BMR of participants at age 11-12 and 16-18 years.

	11-12 years old		16-18 years old	
	Males	Females	Males	Females
Energy intake (MJ/day)	8.38	7.70	12.48	9.40
BMR[1] (MJ/day)	6.13	5.98	7.66	6.12
EI:BMR	1.39	1.30	1.65	1.60

[1] Formula for the prediction of BMR (Schofield *et al*., 1985)
Males age 10 to 17 years = 0.074 (wt)* + 2.754 Males age 18 to 29 years = 0.063 (wt)* +2.896
Females age 10 to 17 years = 0.056 (wt)* + 3.434 Females age 18 to 29 years = 0.062 (wt)* + 2.036

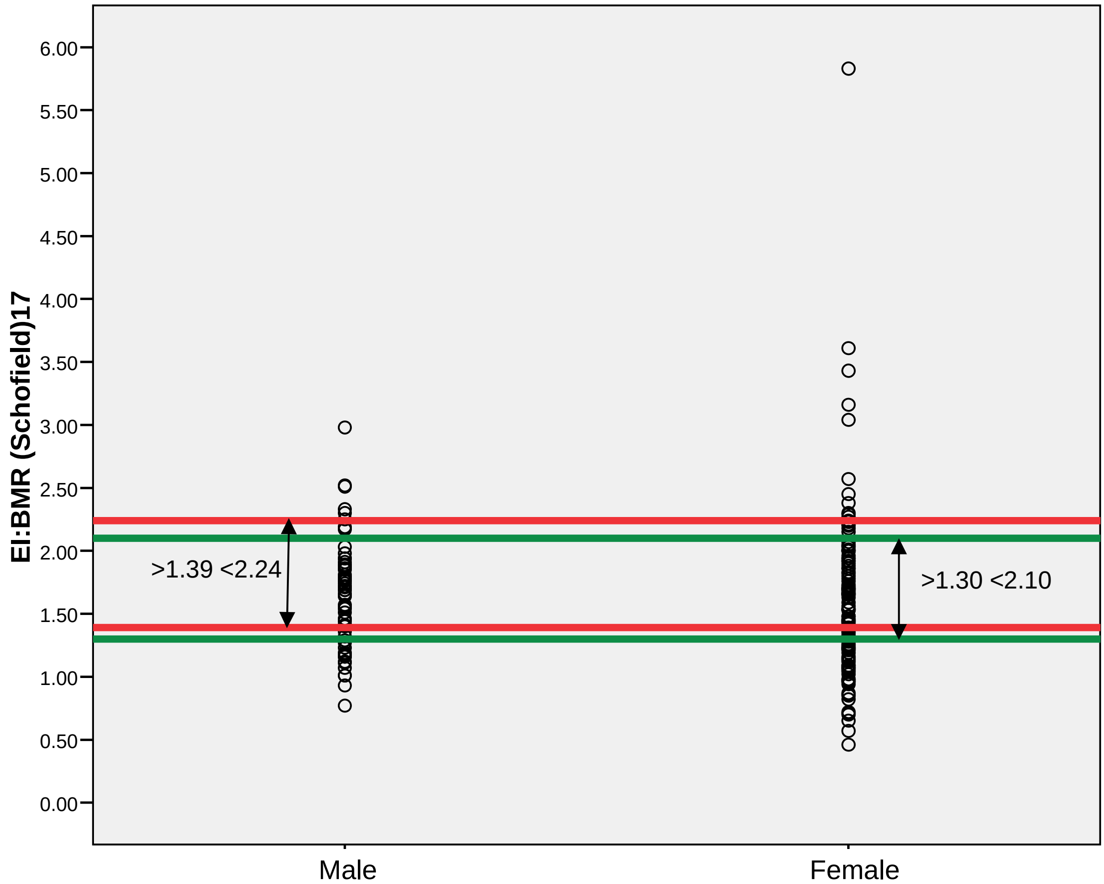

Figure 5.1 Ratio of Energy intake to Basal Metabolic Rate. Illustration of participants reporting energy intakes above and below EI:BMR cut-offs as defined by Torun *et al.*(1996) (<1.39 >2.24xBMR males; <1.30 >2.10xBMR females) at age 16-18 years.

Females were more likely than males to be low energy reporters, at age 11-12 years 59% of females were identified as low energy reporters compared with 52% of males (Table 5.11). Although a decrease (37% total sample) in the prevalence of suspected low reporting was observed as participants matured, females (42%) continued to be more likely than males (26%) to report low energy intakes unlikely to reflect usual intakes (Table 5.11, Figure 5.1). Pearson correlation analysis revealed a significant positive association between EI:BMR at age 11-12 years and at 16-18 years (R=0.44, p<0.01) indicating that those who reported higher EI at age 11-12 years continued to do so at age 16-18 years (Not illustrated). Figure 5.2 shows that the level of persistent low-reporting (that is individuals who reported lower than anticipated EI at both age 11-12 years and 16-18 years) was substantial and was also more common in females (34%) than males (18%). ‘Over’-reporting was not evident in participants at age 11-12 years (Table 5.11), but at age 16-18 years a significant minority of participants (13% males; 12% females) reported intakes above the upper cut-offs defined by Torun *et al.* (1996) (>2.24 x BMR males; >2.10 x BMR females) (Table 5.11and Figure 5.1).

Table 5.11 Prevalence of evidence of reporting bias (Torun *et al.*1996) in participants at ages 11-12 years and 16-18 years.

	% participants at 11-12 years old		**% participants at 16-18 years old**	
	Males <1.39 x BMR Females <1.30 x BMR	Males >2.24 x BMR Females >2.10 x BMR	Males <1.39 x BMR Females <1.30 x BMR	Males >2.24 x BMR Females >2.10 x BMR
Total sample	57	0	37	13
Males	52	0	26	13
Females	59	0	42	12

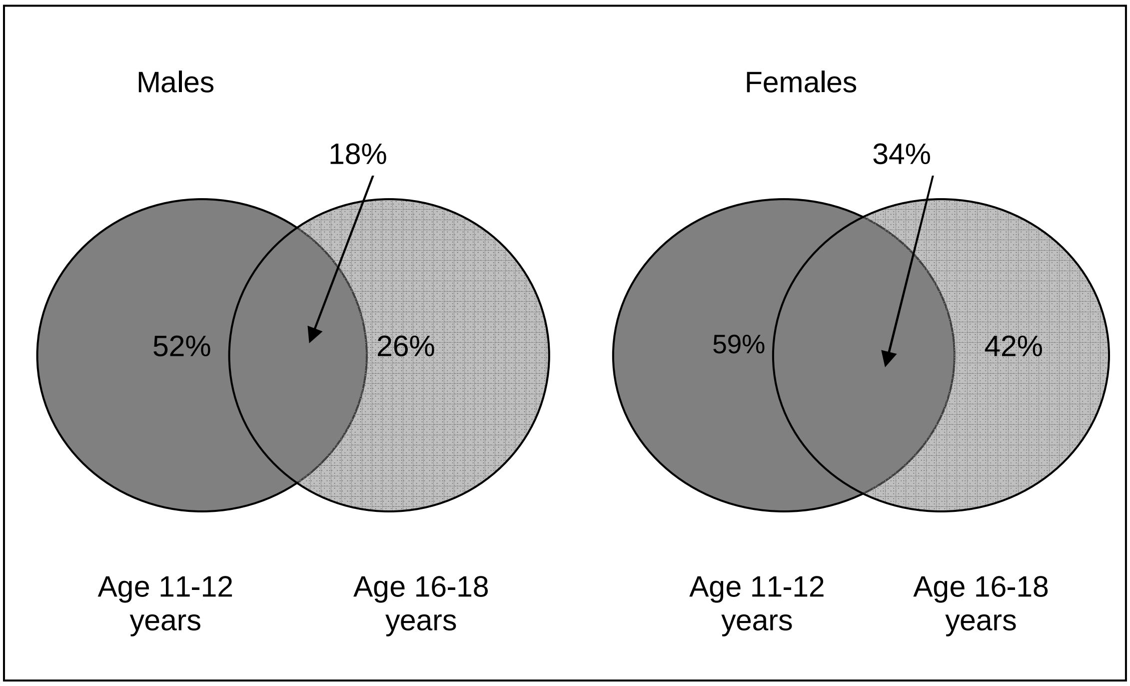

Figure 5.2 Percentage of participants reporting low energy intakes (<1.39 x BMR males; <1.30 x BMR females) at age 11-12 years, age 16-18 years and at both time points.

The Kruskal-Wallace test was used to identify any social disparity in energy reporting, and revealed little effect of social group on EI:BMR ratio at age 11-12 years (p=0.94 males; p=0.70 females) or at age 16-18 years (p=0.12 males; p=0.57 females) (Not illustrated).

There were significant negative associations between BMI and EI:BMR ratios at age 11-12 years (R=-0.49 males; R=-0.52 females, both $p<0.01$) and at age 16-18 years (R=-0.28, $p<0.05$ males; R=-0.41 females, both $p<0.01$) (Figure 5.3 and Figure 5.4). A stronger relationship was observed at age 11-12 years than at age 16-18 years, suggesting that reporting of dietary intake was affected more by BMI at age 11-12 years than at age 16-18 years.

The influence of weight status on the reporting of energy intake was explored further by estimating the prevalence of low-energy and high-energy reporting among normal weight and overweight or obese participants. Table 5.12 reveals that at age 11-12 years nearly twice as many overweight/obese participants (85%) reported low energy intakes compared with normal weight participants (45%). Whilst this difference had decreased at age 16-18 years the prevalence of low energy reporting remained higher in overweight/ obese participants (50%) than among those of normal weight (33%). At 16-18 years of age the influence of weight status on low EI:BMR was more evident in female overweight/obese participants (60%) than in overweight/obese male participants (38%) (Table 5.12). Of the participants (12% of females (n=15) and 13% of males (n=9)) who reported intakes above the cut-offs defined by Torun *et al.* (1996) (Table 5.11), all of the females and seven of the males exhibited normal BMI and two males were classified as overweight.

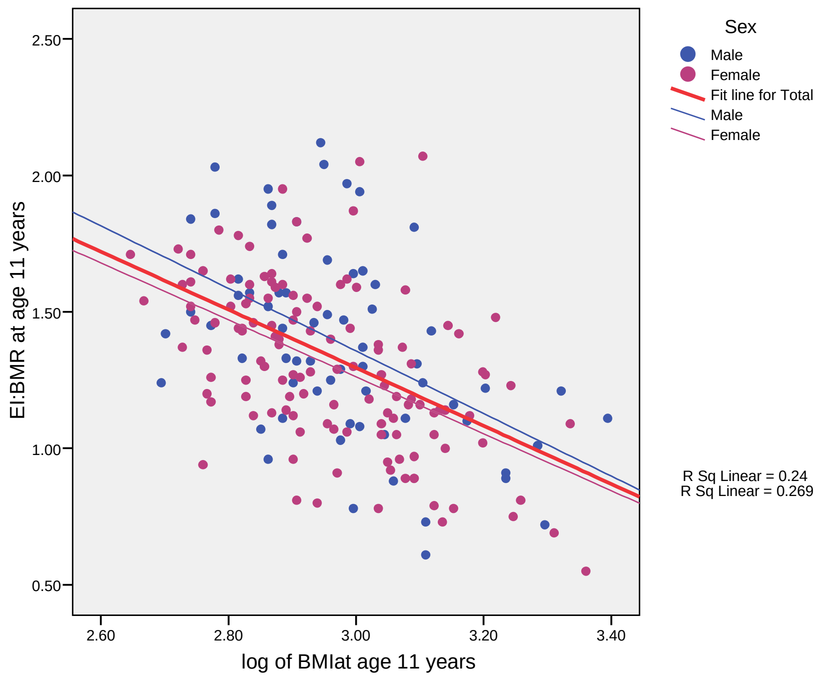

Figure 5.3 Influence of BMI (kg/m2) on reported EI:BMR at age 11-12 years

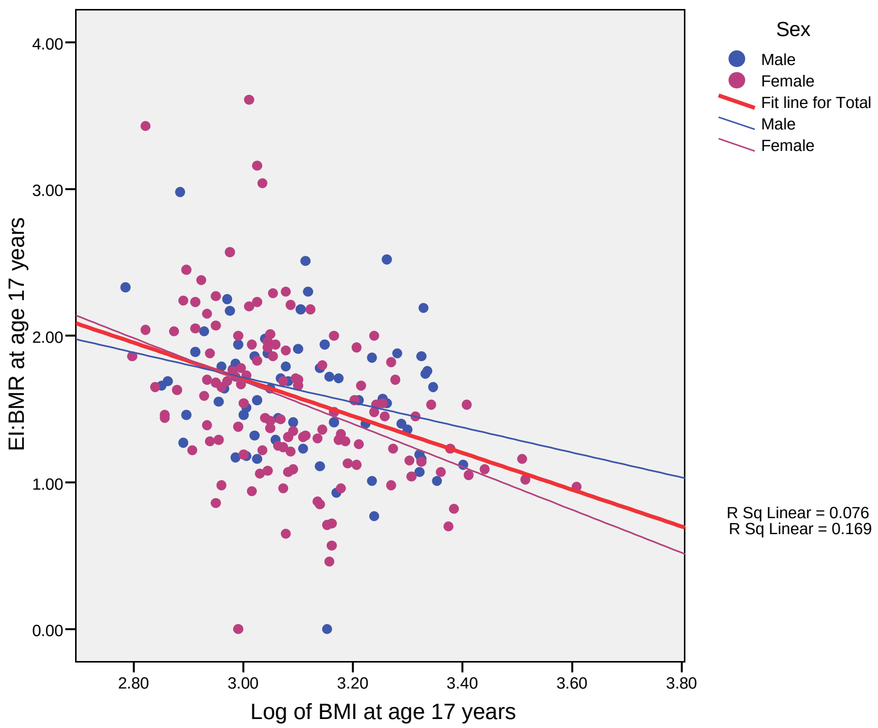

Figure 5.4 Influence of BMI (kg/m^2) on reported EI:BMR at age 16-18 years

Table 5.12 Per cent of low energy reporters among normal weight* versus overweight or obese*.

	Age 11-12 years		Age 16-18 years	
	% Normal weight participants	% Overweight/ obese participants	% Normal weight participants	% Overweight/ obese participants
Total sample	45	85	33	50
Males <1.39 x BMR	39	88	20	38
Females <1.30 x BMR	48	84	38	60

***defined using age and gender specific international cut-offs (Cole *et al.* 2000)**

Summary of Chapter 5.3

- Over 50% of participants were low reporters at age 11-12 years; this prevalence of low reporting in both males and females decreased as participants matured.
- Females were more likely than males to report low energy intakes at age 11-12 and 16-18 years and were almost twice as likely to report low intakes persistently.
- Participants with higher BMI were more likely to report lower energy intake in relation to their BMR than those with lower BMI's.
- At age 16-18 years the influence of weight status was more evident in females than in males.

5.4. Discussion

The aim of this chapter was to assess how representative the 2006 sample was of the 2000 study cohort (ASH 11 Study) from which it was drawn and of a national sample of a similar age (the National Diet and Nutrition Survey (NDNS) of 4-18 year olds (Gregory *et al.* 2000). The methods by which the 2000 study cohort was obtained are described elsewhere (Fletcher *et al.* 2004).

5.4.1. How representative of the 2000 study cohort were these young people at follow-up in 2006?

This follow-up study (2006) comprised 193 of the original 2000 cohort of 424 (Chapter 4.1). Whilst there was a fairly even gender distribution at baseline, only 34% of males compared with 55% of females participated in the follow-up (2006) study. Although both males (90%) and females (62%) from the unclassified (Chapter 3.2) social groups were less likely to take part in this follow-up study, the number of subjects in the unclassified group was small and on the whole, social group appeared to have little effect on follow-up recruitment. The social group distribution of participants in 2006 was similar to that of the 2000 study with relatively high proportion of participants from the high social group in both studies (58% males, 55% females; 49% males, 45% females, respectively).

On the whole there was little difference in height, weight or BMI at age 11-12 years between participants and those who chose not to take part in this follow up study. Adolescence is a period when females in particular are concerned about their weight (Chapter 2.3.1) and, given that female non-participants were on average 2.3kg heavier than female participants when aged 11-12 years, being heavier may have influenced their decision not to take part in this follow-up study. This notion is also supported by the observation that both males and females who were obese at age 11-12 years (n=29) were less likely to take part in this follow-up study (n=22). Given the tracking of BMI between early and late adolescence (Chapter 6) the data reported in this thesis pertaining to adiposity may be an underestimation of the prevalence in young people in Northumberland because a smaller proportion of the obese children at age 11-12 were followed up at age 16-18 years. Reported energy intake and contributions made by the macronutrients to energy intake at age 11-12 years were highly representative of the original study sample for both genders.

5.4.2. How representative of a national study of young people aged 15 to 18 years were these follow-up study participants?

Comparisons of the 2006 recruitment with that of the National Diet and Nutrition Survey (15 to 18 year old age group)(Gregory *et al.*2000) revealed similar challenges in recruitment. Males in particular were less likely than females to take part in this follow-up study as was the case in the 15 to 18 year olds of the NDNS. The main reasons were “reportedly busier and less predictable lifestyles than those of the younger people (age 4 to 14 years)” (Gregory *et al.* 2000) (Chapter 4.3).

In terms of primary education/employment, males were more likely to be representative of the NDNS participants. Females however were less likely than those of the NDNS to have left full time education. This may be in light of secular changes to government policy to encourage teenagers to remain in full time education (http://ema.direct.gov.uk).

A lower proportion of participants in the present study were current smokers and a significantly greater proportion consumed alcohol compared with the 15 to 18 year olds in the NDNS study. The difference in figures between studies may be explained largely by the different methods of data collection. In particular, in the NDNS study those who had ever tried smoking - even just a puff or two of a cigarette were included in the category of ex-smoker, whereas in the present study, participants were questioned about regular smoking activity, defined by smoking more than one cigarette on a regular basis (Chapter 3.5). The lower prevalence of smoking in this study may be in response to greater health awareness which reflects a general reduction in smoking prevalence in the UK (www.statistics.gov.uk) although the reasons for smoking or not smoking were not investigated in this study.

Given the age of participants in both studies (i.e. less than age 18 years), it is plausible that lower reported alcohol consumption by participants of the NDNS may be have been as a result of under-reporting. There are also known regional variations in alcohol consumption (Office of National Statistics, 2001) with a greater proportion of both men and women in the North East of England drinking alcohol than in other regions of England and this may be true of adolescents also. In the NDNS a proportion of the population were from ethnic backgrounds and abstaining from alcohol may form part of their culture and thereby decreasing the proportion of alcohol consumers. In comparison, almost all participants in the present study were White British (Chapter 4.2) and the higher prevalence of alcohol consumption in the present study may in part be as a consequence of the absence of participants from ethnic backgrounds or similar cultures. These reported differences may also be as a result of secular changes in alcohol consumption patterns of young people (www.tradingstandards.gov.uk).

Males in the present study tended to be more similar to those in the NDNS in terms of anthropometry. However the prevalence of overweight and/or obesity among males in the present study (30% overweight; 31% overweight and obese) was notably higher than in the NDNS (20% overweight; 24% overweight and obese). The most likely reason for this difference is due to the year on year increase in overweight and obesity, particularly among males (Butland *et al.* 2007).

Energy intakes were higher in the present study than in the NDNS for both males and females. This was a reflection of higher absolute intakes (g/d) of all macronutrients (fat, carbohydrate and protein). These findings may be explained in part by the higher prevalence of overweight in the present study, for example energy requirements may be greater as a result of the increased body size but similarly, prevalence of overweight might be as a consequence of the higher intakes. Encouragingly % EI from fat was lower than in the NDNS for both males and females, however this was reflection of a higher % EI from alcohol in the present study (both % EI from carbohydrate and protein were also lower than in the NDNS.

When comparing nutrient data of the study sample with the national sample it was evident that there were significant differences between studies. There are a number of potential reasons for this: the age range of the NDNS study sample is 15 to 18 years, compared with 16-18 years in this study sample, when between the ages of 15 and 16 years significant changes may occur (Chapter 6); as mentioned there is also a possibility of under-reported dietary data (Rennie *et al.* 2005) and that choice of dietary methodology were different (Chapter 3.8). The NDNS used a weighed intake methodology whereas participants of the present study estimated their portion sizes with the aid of a photographic food atlas (Nelson, 1997) (Chapter 3.3).

The National Diet and Nutrition Survey (Gregory *et al.* 2000) is a comprehensive cross-sectional survey of the dietary habits and nutritional status of the population in Great Britain (Chapter 2.3) and is the only comparable study of this age group with this quality of data, in the UK to date. However, there is almost a decade (1997/2006) between the data collection periods of the studies and there is a strong possibility that secular changes have taken place and diets of this age group have changed over this period.

5.4.3. Validity of the dietary data

Validation of dietary assessment methods has widely recognised that misreporting of dietary intake occurs (Torun *et al.* 1996); under-reporting in particular is a common source of error in epidemiological studies (Chapter 2.4). Validation in this study was by comparison of reported dietary intake with estimated BMR (Schofield *et al.* 1985a) to calculate EI:BMR. However this approach also has its limitations. For example the use of the ratio EI:BMR assumes that an individual is in energy balance and does not take into account participants who may have intentionally altered their intake to either gain or lose weight. The remainder of this chapter will discuss some of the sources of error which can influence dietary data.

Although a decrease (37% total sample) in the prevalence of suspected low reporting was observed as participants matured, females (42%) were more likely than males to be low energy reporters (Figure 5.2) which may be as a result of dieting (Ward *et al.* 2007), particularly common in this age group where body image is one of many concerns (Neumark Sztainer *et al.* 2007; Fulkerson *et al.* 2004). Interestingly for females in particular, persistent low-reporting was substantial with 34% of those who were low reporters at age 11-12 years were also low reporters at age 16-18 years. This may be attributed to forgetfulness or lack of compliance when faced with unstructured eating events such as eating out of the home (Livingstone *et al.* 1992).

'Over'-reporting is less commonly reported and was not evident in participants at age 11-12 years, but at age 16-18 years a significant minority of participants (13% males; 12% females) reported intakes above the upper cut-offs defined by Torun *et al.* (1996) (>2.24 x BMR males; >2.10 x BMR females). Aside from the fact there may be some participants who have simply mis-reported their intake (Chapter 2.4). These findings could indicate that the physical activity levels in these participants may be greater than identified from the activity data (Chapter 4.2.3). For example taking part in dancing or other sports such as rugby (Chapter 4.6). There may be some cases of participants having a high metabolism where the effects of high energy intakes may not be revealed at this age (except possibly in the two males who were overweight), however the effects may be revealed in adulthood. There is also the possibility that the intakes of these participants was greater than their overall daily requirement, but it might be that this is not representative of usual intake on a weekly basis. At age 16-18 years for many young people is a stressful period and many of these young people were assessed during examination periods. During this time some may go through a period of increased energy consumption (Michaud *et al*. 1990; Weidner *et al.* 1996; Oliver and Wardle. 1999) which may offer some explanation for the small number of suspected over-reporters.

Encouragingly, there was a strong positive association between EI:BMR at age 11-12 years and 16-18 years (R=0.44, p<0.01) which may mean that high (or low) energy consumers remain high (or low) energy consumers in late adolescence. To my knowledge there are currently no other data of this age group with which to compare these findings. One explanation for the strong correlation may be that these findings reflect perceptions of diet and participants' ability or willingness to record accurate data. It should also be considered that when applying cut-offs that participants within the accepted range may have also under-reported their intake, possibly to a greater extent than those identified outside the accepted range (Torun *et al.*1996). For example the actual EI:BMR of a female low reporter may be 1.30 x BMR but their reported intake is 1.20 x BMR and therefore falls below the cut-off (1.30 x BMR females). In contrast, a participant whose actual EI:BMR is 1.80 x BMR but their reported intake is 1.40 x BMR will not be identified as having misreported their EI (Torun *et al.*1996).

In agreement with other studies of adolescents (Bandini *et al.* 1990; Bratteby *et al.* 1998) and adults (Craigie *et al.* 2004; Ward *et al.* 2007) participants with higher BMI's were more likely to report lower energy intake in relation to their BMR than those with lower BMI's at both age 11-12 years and 16-18 years (Figure 5.3 and Figure 5.4 respectively). The association was stronger in females than males at both ages and was also reported by Johansson *et al.* (1998) and Sichert-Hellert *et al.* (1998) but in contrast to findings of Braam *et al*. (1998) and Craigie *et al.* (2004), Livingstone *et al.* (1992) found no significant gender difference in under-reporting in children and adolescents when using DLW to validate the weighed intake and dietary history methods. The observation that the relationship was stronger at age 11-12 years than at age 16-18 years for both males and females might reflect general under-reporting at age 11-12 years. It is plausible that participants may have lower energy expenditure and subsequently lower energy intake relative to BMI or a combination of these, however there are no data at age 11-12 years with which to compare physical activity data at age 16-18 years (Chapter 4). Similarly, although physical activity data were recorded for 50% of these participants at age 16-18 years, to date there are no validated methods by which to convert activity data into energy expenditure (Corder *et al.* 2007). Due to secular increases in prevalence of overweight/obesity in recent years (IOTF, 2007; Butland *et al.* 2007) a higher BMI at age 16-18 years may be perceived as 'normal' and therefore more socially acceptable. This might suggest that the reporting of diet might be less affected by social desirability (BMI) particularly as participants 'mature' (age 16-18 years).

5.4.4. Instrumentation bias – food diary and interview

To minimise error in dietary recording the same method was used at baseline (age 11-12 years) and at follow-up (age 16-18 years). However given the age difference of participants and their ability to provide more information some changes were inevitable. The original food diary (used in 2000) was designed to fit into the pocket of the child at school. However whilst maintaining the original format the diary used in 2006 was increased to accommodate detailed information (Chapter 3). Minor changes were made such as adding an area at the back of the diary to record recipes.

Whilst the method of recording primary food intake data remained relatively unchanged the method of portion size estimation was changed. Food models were used in 2000 to allow comparisons with previous studies of children of the same age in the same schools in 1980 and 1990 (Hackett *et al.* 1982; Adamson *et al.* 1992). In adults there is good evidence to support the use of photographs to estimate portion size and nutrient intake (Nelson *et al.* 1994; Robinson *et al.* 1997; Gerber *et al.* 1997) but evidence of the utility of food photographs in late adolescence is scarce. Age specific food atlases have been produced since (Foster *et al.* 2006) with the oldest age range being 11 to 16 years. For the present study at 16-18 years it was deemed appropriate to use Nelson *et al.* (1997) food atlas for use in adults.

Whilst in most cases the interview was carried out in the school at both time points, some participants who had left school or were on study leave were interviewed at their home (Chapter 3). In a small number of cases where a parent of the participant was at home at the time of interview, the participant was prompted and inadvertently assisted the recall of dietary information. Whilst this potentially increases the accuracy of the information it does introduce a possible reporting bias in respect of other participant data and of the data at age 11-12 years.

5.4.5. Intra-observer variation

Both the 2000 and 2006 studies were carried out by only one nutritionist thereby reducing the intra-observer variation at each time-point. However when comparisons are made between studies it is important to bear in mind that different nutritionists carried out each study. Measures were taken to minimise any possible bias by following the same protocols (Appendix 12) and carrying out a pilot study to provide training for the nutritionist carrying out the 2006 study (Chapter 3).

5.4.6. Errors in the coding, entering and cleaning of the data

The coding of food diaries can introduce error when foods consumed are not allocated to codes of foods with the closest nutritional match. This was limited by collecting food packaging from participants, consulting manufacturers for weights and nutritional information and checking food labels in supermarkets before matching the nutritional information with that of the most similar food code. A common error is applying ‘cooked’ or ‘wet’ weight of foods the energy values for ‘raw’ or ‘dry’ foods that appear in composition tables. However all efforts were made to ensure dietary data were entered into the database correctly. Errors were limited by programming some automatic checks into the Access database, such as a food weight limit of 568g (equivalent to 1 pint) and a food code limit of five digits. All entries were checked at least once after entry of a food diary and before nutritional output was obtained the data were cleaned, for example by examining minimum and maximum weights, and comparing any dubious entries with the food diary. Further checks were carried out on a random selection of 50 diaries by means of double entry, that is, the diaries were entered by one person and then checked by re-entering the same diary again onto the database to ensure all information was coded correctly and that the weights were entered correctly.

5.4.7. Testing bias

Testing bias can be introduced when the measurement influences subsequent behaviour. In the present study, there was a risk that the process of collection of anthropometric measurements might influence dietary recording. This was avoided by taking all anthropometric measurements at the conclusion of the second food diary interview (Chapter 3).

6. CHANGES AND TRACKING IN ADIPOSITY FROM AGE 11-12 YEARS TO 16-18 YEARS

Chapter overview

Introduction

Being overweight as an adolescent is associated with being overweight as an adult (Lean, 2000; Guo *et al.* 2002; Craigie *et al.* 2004), in addition there is some evidence that eating habits formed in adolescence continue into adulthood (Lake *et al.* 2004a). There is interest in the tracking of health-related behaviours and of adiposity as such information can inform policy and direct interventions to focus on age-groups or life stages which are likely to be most effective in promoting lifelong healthy lifestyle behaviours.

Tracking has been defined as the maintenance of relative position in rank of behaviour over time (Kelder *et al.* 1994) (Chapter 2.5), such that from a public health perspective participants who rank highly for disease risk (Twisk, 2003) (from adiposity and/or dietary behaviour for example) at a young age are likely to maintain their ranks through into adulthood (Boreham *et al.* 2004) (Chapter 2.5.1).

The aim of this chapter is to identify changes in, and tracking of, adiposity from 11-12 years to 16-18 years (Chapter 1).

At age 11-12 years, only height and weight were measured, from which BMI was calculated and therefore BMI was also used as the main measure of adiposity at age 16-18 years (Chapter 3.6).

6.1. Changes in measured anthropometry between age 11-12 and 16-18 years

This section reports the changes in anthropometry (height, weight and BMI) between the two time periods, tested using paired t-tests. Differences between males and females at each time point were tested using independent sample t-tests

Anthropometric data were found to be non-normally distributed so the data were $\log_e$ transformed before analysis. For presentation of summary results, $\log_e$ means were back transformed to produce geometric means (Table 6.1). In Table 6.1 ‘mean ratio’ represent the ratio of the geometric means, that is mean (geometric) at age 16-18 years divided by mean (geometric) at age 11-12 years. A value greater than one indicates an increase over time, and a value less than one indicates a decrease over time.

6.1.1. Height

The average height of all present study participants at age 11-12 years was 1.52m increasing to 1.68m (p<0.001) by the age of 16-18 years. At age 11-12 years there was little gender difference (p=0.78), but by the age of 16-18 years males were, on average, significantly (p<0.001) taller (1.78m) than females (1.63m) (Table 6.1).

6.1.2. Weight

At age 11-12 years the average weight of all present study participants was 45.6kg and males were slightly but not significantly (p=0.93) heavier than females (44.9kg and 44.7kg respectively). At age 16-18 years this gender difference was significantly greater (*p*<0.001) with an increase of 58% (26.1kg) observed in males (mean weight 71.0kg) compared with an increase of 32% (14.3kg) in females (mean weight 59.0kg) (Table 6.1).

6.1.3. Body Mass Index (BMI)

Given the similarity in both height and weight of males and females at age 11-12 years it followed that average BMI (weight (kg)/height(m^2)) at this age was similar (19.6 males; 19.3 females) (p=0.53). This lack of difference in BMI by gender continued into late adolescence with male BMI (22.4) being only slightly higher than female BMI (22.2) (p=0.58) at age 16-18 years (Table 6.1). However, as discussed in Chapter 4, bio-impedance analysis (%body fat) revealed that males were significantly leaner than females (p<0.001) at age 16-18 years. Conversely, at age 16-18 years, males on average had a higher waist circumference and subsequent higher waist to hip ratio (both p<0.001) than females (Chapter 4). Pearson correlation analysis revealed that there were strong relationships (Figure 6.1) between BMI at age 11-12 years and all measures of adiposity (BMI, % body fat, WC) at age 16-18 years for both males (p<0.001) and females (p<0.001) (Figure 6.1).

Table 6.1 Change in height, weight and BMI between age between age 11-12 and 16-18 years

		Change in measurement				
		Mean		Mean ratio[1]	95% CI	
		11-12 years	16-18 years	16-18/ 11-12 years	Lower	Upper
Height (m)	All	1.52	1.68	1.11*	1.10	1.12
	Male	1.51	1.78	1.18*	1.17	1.18
	Female	1.52	1.63	1.07*	1.07	1.08
Weight (kg)	All	44.8	63.0	1.41*	1.37	1.44
	Male	44.9	71.0	1.58*	1.52	1.64
	Female	44.7	59.0	1.32*	1.29	1.35
BMI (kg/m^2)	All	19.4	22.2	1.14	1.12	1.16
	Male	19.6	22.4	1.14	1.11	1.18
	Female	19.3	22.2	1.15	1.12	1.17

[1] Ratio = Geometric mean at age 16-18 years divided by geometric mean at age 11-12 years. A value > 1 indicates an increase over time, and a value <1 indicates a decrease over time.

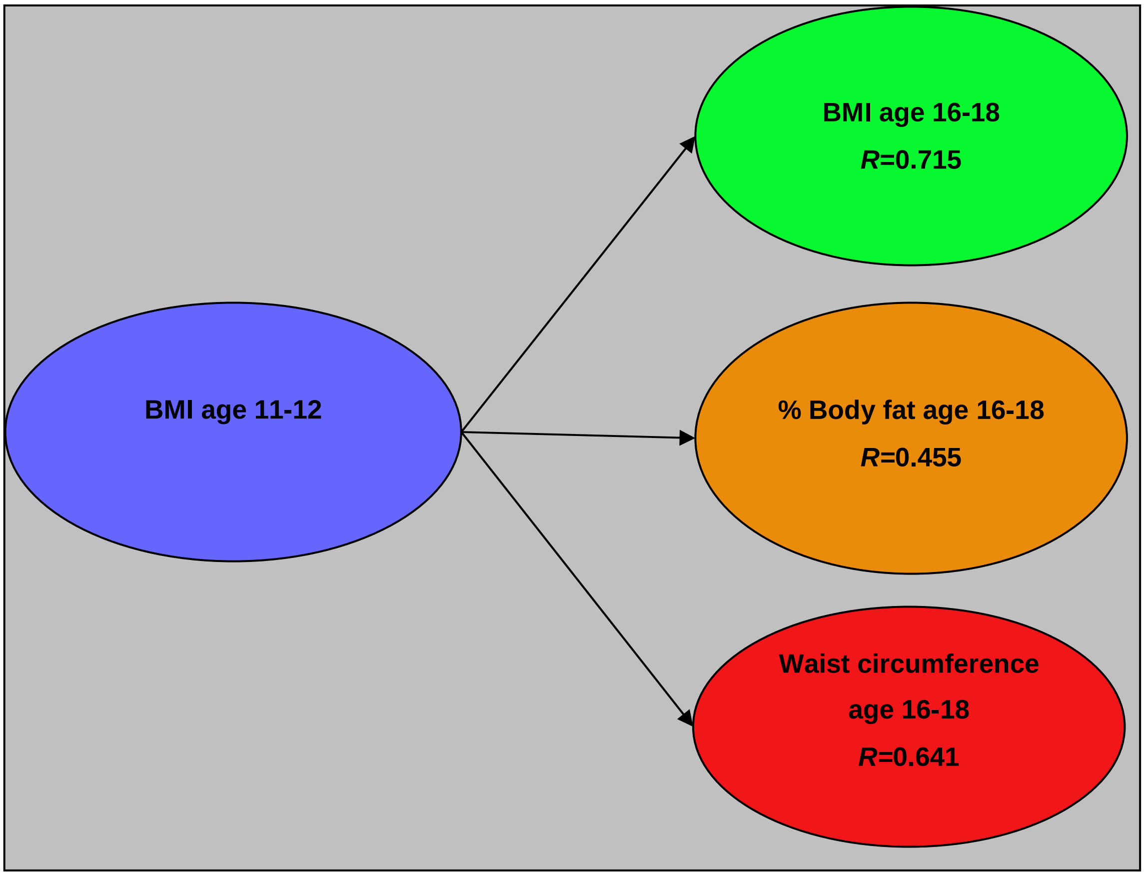

Figure 6.1 Pearson correlation between BMI at age 11-12 years and measures of adiposity at age 16-18 years.

6.1.4. Change in prevalence of overweight and obesity between age 11-12 and 16-18 years

At age 11-12 and 16-18 years age and gender specific international cut-offs were used to categorise participants by their BMI (normal, overweight or obese) (Cole *et al*. 2000) (Chapter 3). At age 11-12 years there was a greater prevalence of overweight among the whole sample than at age 16-18 years (25% and 20% respectively). The prevalence of obesity however remained unchanged at 4% of all participants (Table 6.2). There were discordant changes between the two sexes in proportions of obese and overweight subjects over the 6 years between measurements. The percentage of overweight male participants (21%) increased (+9% points) whilst the percentage of obese males (6%) decreased (-5% points). Conversely, the percentage of overweight female participants (27%) decreased (-12% points), whilst the percentage of obese females (2%) increased (+3% points).

Table 6.2 Change in prevalence of overweight and obesity at age 11-12 and 16-18 years

Gender		**BMI class**			
	No.	Overweight n (%)		Obese n (%)	
		Age 11-12 years	Age 16-18 years	Age 11-12 years	Age 16-18 years
Male	67	14 (21)	20 (30)	4 (6)	1 (1)
Female	123	34 (27)	19 (15)	3 (2)	6 (5)
All participants	190	48 (25)	39 (20)	7(4)	7 (4)

*** Females n=123 as complete BMI unavailable for 3 females (Chapter 4.1)**

Summary of Chapter 6.1

- At age 11-12 years there was little gender difference in height (p=0.78), or weight (p=0.93), but by the age of 16-18 years males were, on average, significantly (p<0.001) taller (1.78m) and heavier (71.0kg) (p<0.001) than females (1.63m and 59.0kg respectively).
- There was little gender difference in mean BMI at either age 11-12 (19.6 males, 19.3 females; p=0.53) or 16-18 years (22.4 males, 22.1 females; p=0.58).
- The prevalence of overweight (all participants) was greater at age 11-years years than at age 16-18 years (25% and 20% respectively). The prevalence of obesity however remained unchanged at 4%.
- There were gender differences in prevalence of overweight and obesity at both age 11-12 and 16-18 years. The prevalence of overweight males (21%) increased (+9% points), whilst the percentage of overweight females (27%) decreased (-12% points). The prevalence of obesity in males (6%) decreased (-5% points) whilst the prevalence of obesity in females (2%) increased (+3% points) by the age of 16-18 years.

6.2. Tracking of BMI from age 11-12 years to age 16-18 years

Tracking, defined as the maintenance of relative position in rank of behaviour over time (Kelder *et al.* 1994), was used to determine the extent to which overweight and obesity in childhood (age 11-12 years) continued into late adolescence (age 16-18 years). In the first instance Pearson correlation was used to determine the relationship between BMI at age 11-12 years and BMI at age 16-18 years (Figure 6.2). Highly significant associations between BMI at 11-12 years and at age 16-18 years for both males (P<0.01, R=0.65) and females (P<0.01, R=0.75) are illustrated in Figure 6.2.

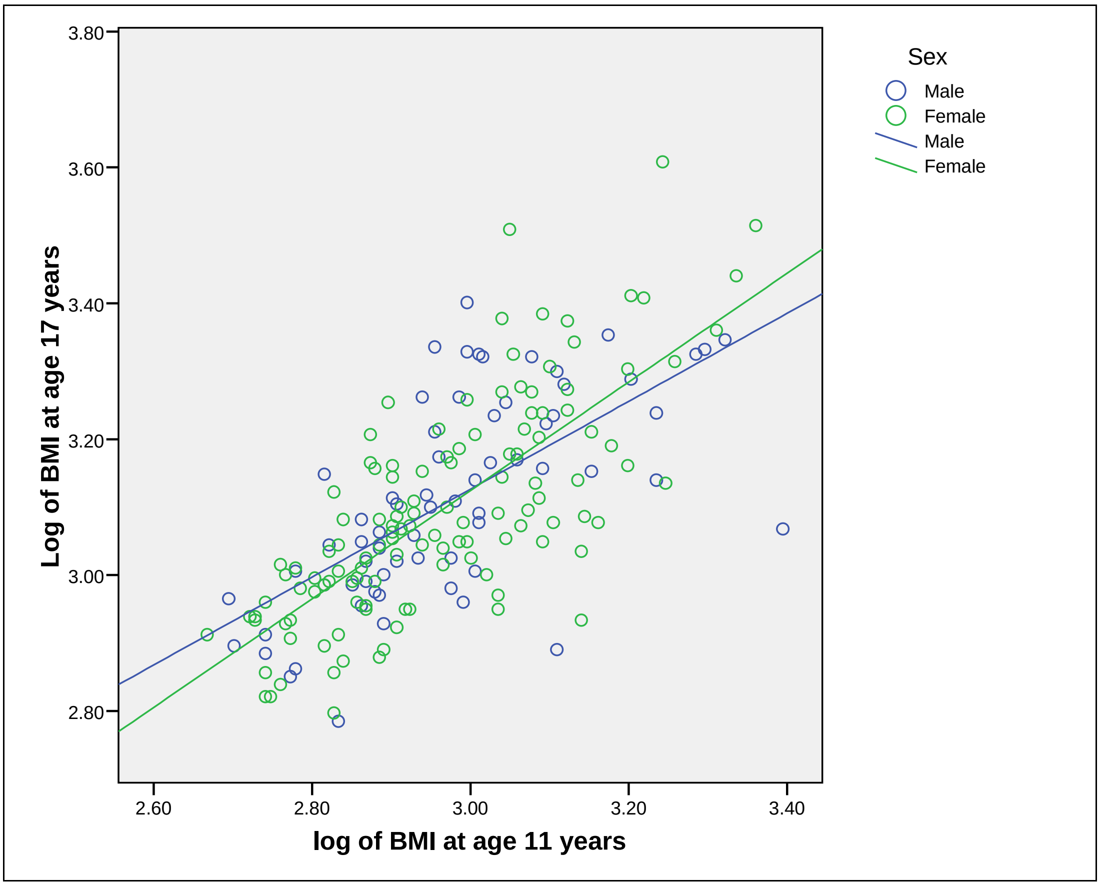

Figure 6.2 Correlation between log$_e$ of BMI at age 11-12 years and log$_e$ of BMI at age 16-18 years

6.2.1. Maintenance of quartile group of BMI

To investigate the percentage of participants who maintained their relative position over the 6 years of study, participants were grouped into quartiles of BMI at age 11-12 years and quartiles of BMI at age 16-18 years. Of those participants who were in the lowest or highest quartiles of BMI at age 11-12 years, over 60% maintained their relative position for BMI i.e. were in the corresponding BMI quartile at age 16-18 years (Table 6.3). Evidence of tracking was stronger in females than in males with 65% maintaining their position in both the highest and lowest BMI quartiles, compared with 53% and 59% respectively of males. The Kappa (*k*) test revealed there was fair (males *k*=0.26; females *k*=0.33) probability (strength of agreement) (Table 6.4) that participants would maintain their quartile position for BMI over the six years of adolescence.

Table 6.3 Maintenance (at age 16-18 years) of quartile position of BMI age 11-12 years

Quartile of BMI at age 11-12 years		**Quartile group of BMI at age 16-18 years**		
	Range of BMI	Gender	Range of BMI	Maintenance of quartile position (%)
Lowest	<17.5	All	<19.9	67
	<17.6	Male	<19.9	59
	<17.3	Female	<19.8	65
Second	17.5 to 19.2	All	19.9 to 21.7	41
	17.6 to 19.3	Male	19.9 to 22.2	38
	17.3 to 18.9	Female	19.8 to 21.6	37
Third	19.2 to 21.6	All	21.7 to 24.8	35
	19.3 to 21.3	Male	22.2 to 25.5	29
	18.9 to 21.7	Female	21.6 to 24.3	34
Highest	>21.6	All	>24.8	60
	>21.3	Male	>25.5	53
	>21.7	Female	>24.3	65

Table 6.4 Strength of agreement (*kappa*) that participants maintain quartile position beyond chance between age 11-12 years and age 16-18 years

	Males			**Females**		
	n	*k**	*p*	n	*k**	*p*
BMI (kg/m-2)	67	**0.26**	**<0.001**	124	**0.33**	**<0.001**

***Strength of agreement: value of *k* <0.20=Poor; 0.21-0.40=Fair; >0.41=Moderate**

To assess BMI values from a health perspective, participants were grouped by their BMI classification (normal, overweight, obese) at age 11-12 years and at age 16-18 years. Figure 6.3 and Figure 6.4 illustrate the percentage of participants at age 11-12 years who had changed or maintained BMI classification at age 16-18 years. In both males and females, participants who were normal weight at age 11-12 years were most likely to maintain their BMI classification at age 16-18 years (82% males, 94%

females). However, it is noteworthy that the one male participant (Figure 6.3) and one of the female (Figure 6.4) participants who were obese at age 16-18 years were in the normal weight category at age 11-12 years.

In males, 64% of those who were overweight at age 11-12 years remained overweight and 36% became normal weight at age 16-18 years. Of those males who were obese, all decreased weight status, with 75% becoming overweight and 25% becoming normal weight status (Figure 6.3). Overall females were more likely than males to maintain their BMI classification. Of those females who were overweight at age 11-12 years 41% remained overweight, 9% became obese and a corresponding 50% became a normal weight. Of those females who were obese at age 11-12 years, 67% remained obese and 33% moved into the overweight classification but none were classified as normal weight at age 16-18 years (Figure 6.4). The Pearson Chi square test revealed significant ($p<0.01$) tracking of BMI classification in both males and females and there were fair (males k=0.38) to moderate (females k=0.47) probability that participants would maintain beyond chance their BMI classification at age 16-18 years.

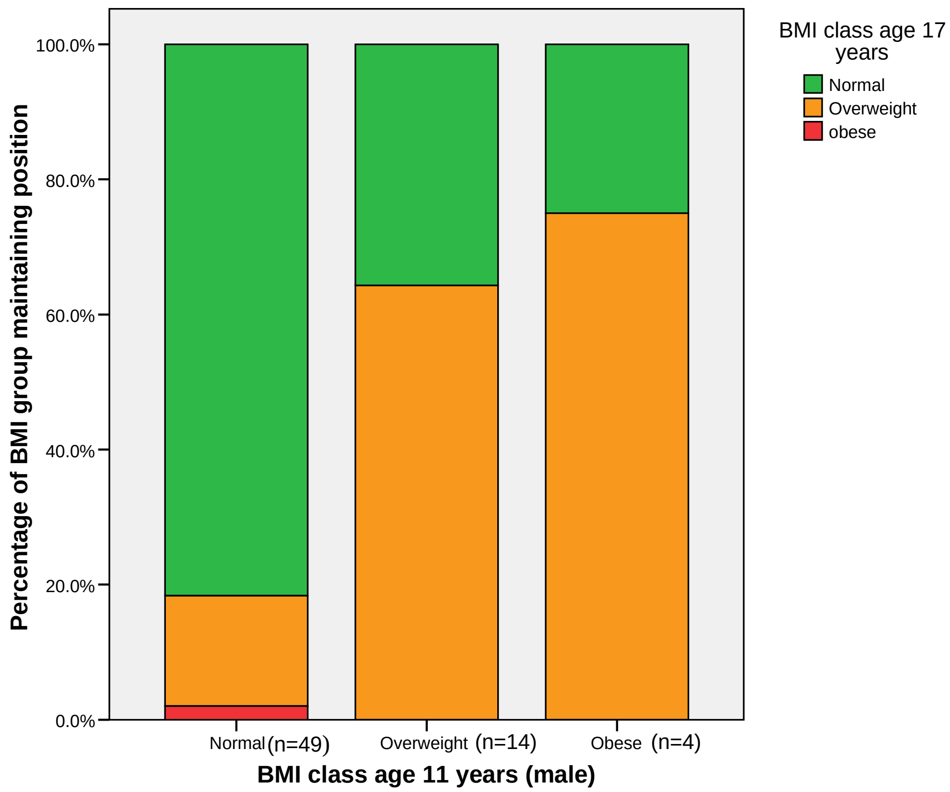

Figure 6.3 Percentage of participants maintaining BMI classification at age 11-12 years into late adolescence (males)

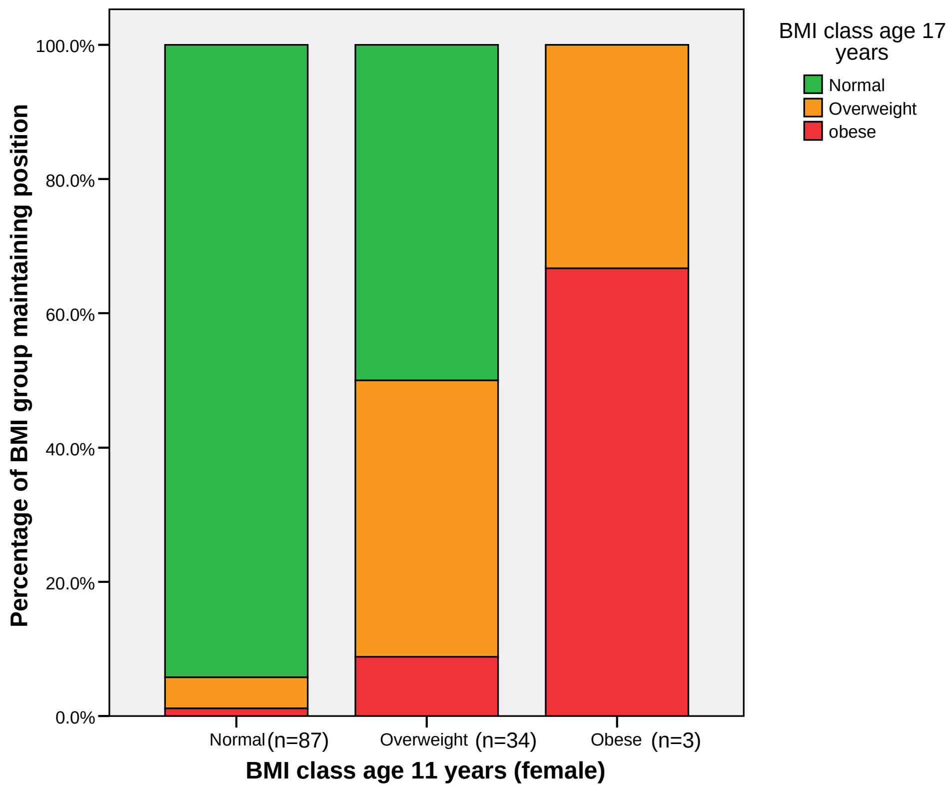

Figure 6.4 Percentage of participants maintaining BMI classification at age 11-12 years into late adolescence (females)

6.2.2. Tracking of BMI by social group

To ascertain any social disparities in the tracking of BMI, participants were grouped by social group and by quartile of BMI at age 11-12 and 16-18 years. Both males and females of the low social group were more likely to remain in the highest quartile of BMI (67% and 100% respectively) than those in the highest quartile of BMI of the high and middle social groups (Table 6.5), but this difference was not significant. Pearson Chi Square tests revealed significant tracking in the high (p<0.01) and middle (p<0.05) social groups of females and only in the high (p<0.05) social group of males. Further investigation revealed fair strength of agreement that participants in each social group would maintain quartile position of BMI at age 16-18 years. There were notable differences between sexes on the influence of social group on BMI. Figure 6.5 for example illustrates the significantly (p<0.05) lower mean BMI of males from the high social group than those of the middle and low social groups at age 11-12 and 16-18 years. While on the other hand, at age 11-12 years females from the low social group had the lowest mean BMI and females from the high social group had the highest mean BMI. At age 16-18 years this scenario was reversed and Figure 6.6 illustrates that there was little, that is no significant social disparity in mean BMI of females at either age.

Table 6.5 Maintenance (at age 16-18 years) of quartile position of BMI (age 11-12 years) by social group

		Maintenance of quartile position of BMI by social group at age 16-18 years (%)		
Quartile group of BMI at age 11 -12 years	Gender	High	Middle	Low
Lowest	All	71	64	50
	Male	69	33	0
	Female	67	71	50
Second	All	48	57	11
	Male	50	0	0
	Female	38	57	20
Third	All	29	33	0
	Male	25	33	0
	Female	25	33	33
Highest	All	56	57	83
	Male	63	57	67
	Female	50	57	100

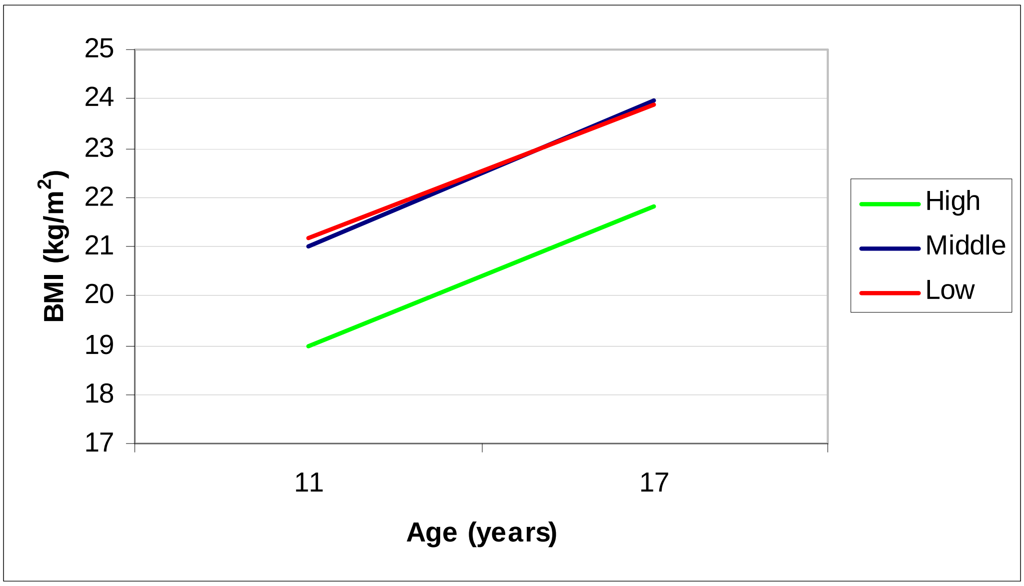

Figure 6.5 Tracking of BMI by social group from age 11-12 years to age 16-18 years (male)

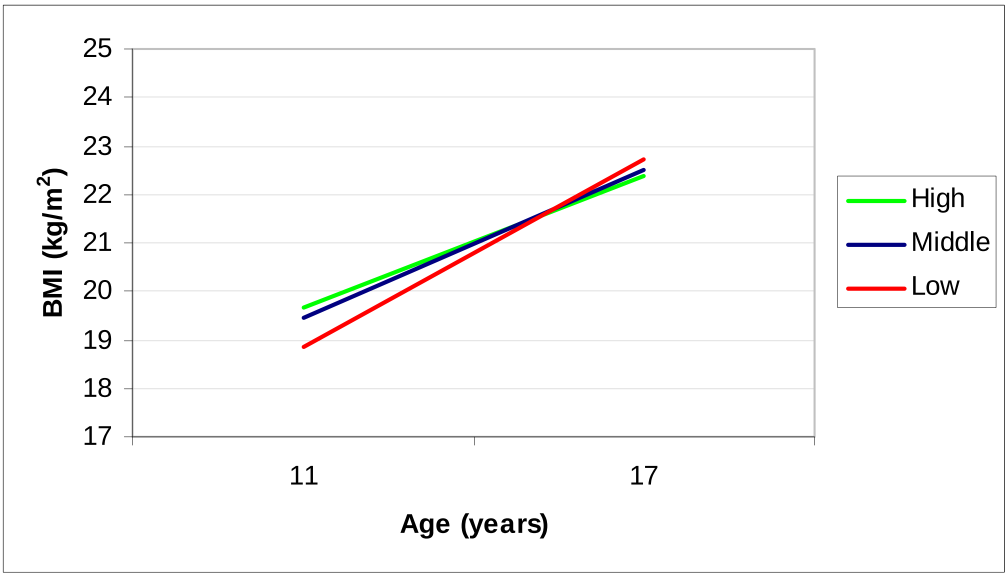

Figure 6.6 Tracking of BMI by social group from age 11-12 years to age 16-18 years (female)

<u>Summary of Chapter 6.2</u>

- These findings show that BMI tracked significantly between ages 11-12 and 16-18 years.
- BMI at age 11-12 years was highly correlated with measures of adiposity (BMI, % body fat, WC) at age 16-18 years.
- Evidence of tracking was stronger in females than males when grouped into quartiles of BMI at age 11-12 and 16-18 years.

- There was evidence of tracking in both males and females when social group was taken into consideration. In males, at age 11-12 and 16-18 years participants from the higher social group had lower mean BMI's than those in the middle and low social groups ($p<0.05$). In females there was no evidence of an effect of social group on BMI. The narrow difference between mean BMI of each social group was not significant at age 11-12 or 16-18 years.

6.3. Discussion

A number of methods are available for the measurement of adiposity (Chapter 2.2.1); however BMI is widely accepted as the preferred measure for evaluating overweight and obesity among groups of children and adolescents age 2 to 19 years (Cole *et al*. 2000) At age 11-12 years, only height and weight were measured, from which BMI was calculated and therefore BMI was also used as the main measure of adiposity at age 16-18 years.

6.3.1. Change in height, weight and BMI during adolescence

In these participants at age 11-12 years height and weight was similar for males and females and each of these measurements increased significantly (p<0.001) over the six years to age 16-18 years. On average between the ages of 10 and 15 years, males gain 26cm in height and 26kg in weight and females gain 23cm in height and 21kg in weight, between the ages of 12 and 17 years (Webb, 2002) (Chapter 2.1). Males increased 27cm in height and 26kg in weight while females increased 11cm in height and 14kg in weight so that, as expected, males were significantly taller and heavier at age 16-18 years. However in females there were notably smaller increases in height (-12cm) and weight (-7kg) than might be expected (Webb, 2002). This could be an indication that a major part of growth in these females took place between age 10 and 12 years; and subsequently making them taller and heavier at age 11-12 years than in previous studies. (Chapter 2.3.1)

There was little gender difference in BMI of these participants in childhood or adolescence. Whilst on average males were significantly (p<0.001) taller and heavier than females (age 16-18 years), there were similar increases in BMI for both genders (males +2.8 units and females +2.9 units). The normal pattern is for BMI to decrease from ≈2 years of age until 5 or 6 years of age and to increase thereafter (Malina, 2004 in Krebs, 2007) (Chapter 2.5.1). It coincides with the period between the ages of 4 and 7 years when BMI reaches its lowest point and then begins to increase through the remainder of childhood and into young adulthood (Dietz, 1997). This narrow gender difference in BMI at age 16-18 years is largely explained by the complication that during adolescence not only height and weight, but also body composition is still changing (Friedman, 1997; Page and Fox, 1998). In addition, as stated (Chapter 2.2.1), the assessment of adiposity by BMI is a proxy measure and does not distinguish between fat and lean tissue, and therefore some highly muscular individuals with low body fat can have a high BMI. Males gain proportionately more muscle and lean tissue than fat and females gain more fat than muscle as part of their natural sexual and reproductive physiology (McCarthy *et al.* 2006). Therefore at age 16-18 years, whilst BMI was similar for males and females, males were on average leaner than females (Chapter 4.2.2).

6.3.2. Change in BMI during adolescence from a health perspective

Significant positive relationships (Figure 6.1) were identified between BMI at age 11-12 years and all measures of adiposity (BMI, % body fat, WC) at age 16-18 years for both males and females. This provides strong evidence that BMI at age 11-12 years in not only indicative of BMI at age 16-18 years but also of % body fat and WC at this age. There is no single explanation for the origin of overweight or obesity in children or adolescents and studies have reported a number of plausible contributory factors. Differences in the age of the onset of puberty for example may affect fat deposition (World Health Organization, 1995; Martinez, 2000). Unfortunately the age of puberty in the participants of this study was not identified and is therefore difficult to say with certainty its effect on BMI of *these* participants. Post pubertal fat deposition in both females and males tends to be more central (waist and hip) rather than general (Lawlor & Chaturvedi, 2006) and may also be a critical period for the development of atherosclerosis. McGill (2000) suggested that late adolescence (i.e. from age 15-19 years) is the key time when fatty streaks convert to raised atherosclerotic lesions (McGill, 2000). This also corresponds with the age at which BMI and skinfold thickness increase in young adults who go on to develop the metabolic syndrome (Ferreira, 2005). More recently, Baker *et al.* (2007) reported data from a cohort of Danish schoolchildren in whom higher BMI at the age of 7 to13 years in boys (age 10 to 13 years in girls) was associated with increased risk of CHD in adulthood (from the age of 25 years). Furthermore the associations became stronger with increasing age of the child, which might suggest that participants in the present study who had a higher BMI at age 11-12 years may be at risk of developing CHD in early adulthood (Chapter 2.2.2). However Baker *et al.* (2007) did not report the BMI of the participants in adulthood, and it is therefore difficult to determine whether children who had a higher BMI (regardless of their adult BMI) or those who continued to have a high BMI as an adult might be at risk.

6.3.3. Change in prevalence of overweight and obesity during adolescence

Encouragingly, on the whole the prevalence of overweight in this sample decreased over time from 25% (27% females; 21% males) at age 11-12 years to 20% (15% females; 30% males) at age 16-18 years. Nevertheless prevalence was higher than in a recent longitudinal study of teenagers (HABITS) (Wardle *et al.* 2006) in which 19% (23% females; 16% males) were overweight at age 11-12 years decreasing to 17% (20% females; 14% males) at age 16 years. However prevalence of obesity at both age 11-12 and 16-18 years (4%) in the present study participants was lower than in the HABITS study (6% at age 11 years and 7% at age 16 years). Prevalence of obesity was also slightly lower than the Health Survey for England, 2004 data (McPherson *et al.* 2007) which found that 5% of boys and 11% of girls in the 11-15 age group were obese. The prevalence for age 17 years specifically was not reported, but in the 16 to 24 age group 8% of males and 13% of females were obese and a further 24% (males & females) overweight (McPherson *et al.* 2007). Comparisons between the lower prevalence of obesity in the present study compared with Health Survey for England is limited. For example all participants in this study were age 16-18 years, and the Health Survey for England also included adults up to age 24 years; It is known that there is a general increase in prevalence of overweight with age (McPherson *et al.* 2007) and subsequently it is difficult to make direct comparisons between the data. It is also plausible that the present study being of a specific area of the UK (i.e. Northumberland) and of a much smaller sample size may therefore under-represent the proportion of obese adolescents (Chapter 5.4). Similarly as discussed in Chapter 5 the proportion of obese participants in this study may be under-represented due to a bias in recruitment of participants (Chapter 5.4.1). Gender differences in prevalence of overweight and obese are discussed in Chapter 4.6.

6.3.4. Tracking of BMI from childhood to late adolescence and adulthood

The most striking observation from this study is that whilst a large proportion of overweight 11-12 year old participants had moved from overweight (36% of overweight males and 50% of overweight females) or obese (25% of obese males only) to normal weight, the majority of participants had maintained their BMI classification status over the 6 years of study (Chapter 6.2.1). Other studies have reported similar findings. For example the number of students from the HABITS study who moved from overweight to healthy weight was 36% and very few (7%) from obese to healthy weight (Wardle, *et al.* 2006). Gordon-Larsen, *et al.* (2004) also reported a small proportion (14.4%) of males (aged 13-20y) moved out of the obese category as they became adults (19-26y). It should also be considered that some children (11-12 year olds) of the present study may have had relatively high weights primarily due to high lean mass, rather than high body fat levels which are not identified by BMI alone (Chapter 2.2). These findings emphasise that being overweight or obese at age 11-12 years greatly increases risk of being overweight or obese at age 16-18 years. However as stated this progression is not inevitable. While a substantial proportion of overweight or obese children at age 11-12 years became normal weight at age 16-18 years, a small proportion of participants in the present study became obese at age 16-18 years (Figure 6.3 and Figure 6.4). Therefore lower weight in childhood should still be a focus of concern since it offers no protection against adult obesity and is associated with increased risk of adult disease (Wright *et al.* 2001).

The finding that BMI tracked significantly from childhood (age 11-12 years) to late adolescence (age 16-18 years) (Chapter 6.2) concurs with other studies (Chapter 2.5.1). In a five year longitudinal study of participants from age 11 to 16 years, Wardle *et al.* (2006) reported that adiposity tracked strongly over time and BMI correlations were greater than 0.9 at one and two year intervals and above 0.8 for three and four year intervals. In agreement with Johannsson, (2006) (Chapter 2.5.1) this indicates that the children who are fatter than average at age 11 years are likely to remain fatter in late adolescence. Similarly, tracking of BMI was stronger in the present study (a 6 year interval) (R=0.65 males, R=0.75 females) than in a longitudinal study of Northumberland adolescents (age 12 years) into adulthood (age 33 years) (20 year interval) (R=0.58 males, R=0.56 females) (Craigie *et al*. 2004).

In a systematic review of the literature from 1985 to 2005 Singh *et al.* (2008) found increased risk for an overweight or obese youth to become overweight or obese in adulthood (Chapter 2.5.1). Guo *et al.* (2002) estimated greater probability of being obese at age 35 years from age 17 to 20 years in both males and females, than from age 12 to 20 years in females and from age 11.5 to 16 years in males. The author went onto suggest if individuals end their adolescence with moderately elevated BMI, then there was a greater likelihood of obesity in later adulthood (for example, age 35 years) (Chapter 2.5.1). Therefore on this basis, participants of this present study who were overweight or obese at age 16-18 years may be at greater risk of being an overweight or obese adult than those who were overweight or obese at age 11-12 years (but not at age 16-18 years).

During adolescence, many young people are concerned with body image (Tiggeman, 2005) and weight issues and some are reported to engage in dieting behaviours to control their weight (Neumark-Sztainer *et al.* 2002; Butland *et al.* 2007) (Chapter 2.3.1) which in part might explain the reduction in weight status, particularly of females.

However Neumark-Sztainer *et al.* (2006) found that dieting and weight control behaviours, particularly unhealthful behaviours (e.g. meal skipping, smoking) at age 12 years were associated with weight gain (rather than weight loss) at age 17 years. Furthermore dieting at age 12 years was associated with higher BMI values and a greater prevalence of overweight status in both males and females (Chapter 2.3.1). Freedman *et al.* (2004) reported that obese children tend to be taller than their lean counterparts and faster growth goes with a larger appetite in general, and this was a plausible explanation for the females who remained obese from age 11-12 to 16-18 years.

Few studies have reported the effect of socioeconomic status on tracking of adiposity. However, prevalence of obesity is reportedly greater in lower social groups (for example HSE, 2004; in Butland *et al*, 2007; Wardle *et al.* 2006). Whilst at age 11-12 years this finding was true for males in the present study, the mean BMI of females was greater in the high and middle social groups. However, at age 16-18 years mean BMI was greater in the low social group for both males and females (though significantly so only for males), suggesting that social disparities in adiposity in females may not become apparent until adulthood. It is important to consider too that when the BMI is subdivided by social group, the number in each BMI category become much smaller so the power to detect social class effects are reduced substantially even if they exist.

7. CHANGES AND TRACKING IN DIET FROM CHILDHOOD TO LATE ADOLESCENCE

Chapter overview

Introduction

There is evidence that some childhood behaviour continues into adulthood and initiation of health-compromising behaviours such as poor dietary intake in childhood contributes to physiological risk factors (e.g. cardiovascular disease) in adulthood (Twisk *et al.*1997).

Because being overweight as an adolescent is associated with being overweight as an adult and because eating habits formed in adolescence continue into adulthood (Lake *et al.* 2004a), it is likely that poor dietary habits in adolescence will have important implications for health and well-being in adulthood (for example (Neumark-Sztainer *et al.* 1999) (Chapter 2).

Continuing on from Chapter 6 which focussed on how these young people had changed in the available measures of body composition (height, weight and BMI) over this period of adolescence (age 11-12 to 16-18 years); The aim of this chapter is to compare the dietary intake from age 16-18 years with that of these young people at age 11-12 years and provides estimates of changes in, and tracking of, diet over this period of adolescence.

Changes, that is, difference in dietary intake between the two time periods were tested using paired t-tests (Table 7.1 to Table 7.3). Differences between males and females at each time point were tested using independent sample tests and are shown in Table 7.4 to Table 7.6.

It is important to note that at age 16-18 years alcohol formed part of the energy intake of several of these participants (Chapter 4.2.3), however this was not the case at age 11-12 years. Therefore to allow true comparisons to be made between the two data, total energy intake in this chapter only, is expressed as 'Food Energy' which excludes energy from alcohol at age -16-18 years. Macronutrients expressed as units of percent energy intake are calculated as a percentage of food energy.

Tracking, defined as the maintenance of relative position in rank of behaviour over time (Kelder *et al.* 1994) (Chapter 2.5), was used to determine the extent to which dietary intake in childhood continued into late adolescence (Chapter 7.2).

7.1. Changes in dietary intake from age 11-12 years to age 16-18 years

The focus of this thesis is energy balance therefore the aspects of participants' diets that are investigated are total energy intake[1] and macronutrient intake. These intakes are expressed as units of absolute intake (MJ/d or g/d), grams per kg body mass (MJ/kg/d or g/kg/d), and the per cent of food energy intake (% FEI) derived from each macronutrient. The average intakes of energy and the macronutrients at age 11-12

[1] At age 16-18 years alcohol formed part of the energy intake of several of these participants, however this was not the case at age 11-12 years. Therefore to allow true comparisons to be made between the two data, total energy intake in this chapter only, is expressed as 'Food Energy' which excludes energy from alcohol at age -16-18 years. Macronutrients expressed as units of percent energy intake are calculated as a percentage of food energy.

and 16-18 years are shown in Table 7.1 to Table 7.6. Change in intake between the two time points and 95% confidence intervals for the change in intake are presented (Table 7.1 to Table 7.3) for the entire sample and for males and females separately. Table 7.4 (MJ/d or g/d), Table 7.5 (% FEI) and Table 7.6 (MJ/kg/d or g/kg/d) present the difference in intakes between males and females at age 11-12 and 16-18 years, and the 95% confidence intervals for the between gender differences.

Where the data were not normally distributed, the data were $\log_e$ transformed to return the data to normal distribution before analysis. These $\log_e$ data were back transformed ($\exp^x$) to produce geometric means (indicated by the symbol ≠) (Table 7.1 to Table 7.6). In Table 7.1 ‘mean differences’ represent the ratio of the geometric means, that is mean (geometric) intake at age 16-18 years divided by mean (geometric) intake at age 11-12 years. A value greater than one indicates an increase over time and a value less than one indicates a decrease over time. Between males and females (Table 7.4 to Table 7.6) ‘mean differences’ represent the ratio of the geometric means between sexes, that is mean (geometric) intake of males divided by mean (geometric) intake of females. A value greater than one indicates a higher intake in males than females and a value less than one indicates a lower intake in males than females. Confidence intervals associated with these data are of the ratio of geometric means.

Table 7.1 Intakes of food energy (MJ/d) and macronutrient ints (g/d) and changes in intakes between ages 11-12 and 16-18 years.

			Mean intake		Change in intake (16-18 years -11-12 years)		
	Units	Sample	11-12 years	16-18 years	Mean difference	Lower CI	Upper CI
Food Energy	MJ/d	All	7.90	9.80	**1.90****	1.50	2.30
		Male	8.40	11.7	**3.30****	2.60	4.00
		Female	7.70	8.90	**1.20****	0.70	1.60
Fat	g/d	All	75.2	93.8	**18.5****	13.9	23.2
		Male	78.5	113	**34.2***	26.9	41.4
		Female	73.5	83.8	**10.3****	4.78	15.7
Carbohydrate	g/d≠	All	254	293	**1.15****	1.10	1.20
		Male	269	338	**1.25****	1.16	1.35
		Female	247	272	**1.09****	1.04	1.15
Protein	g/d≠	All	55.3	79.2	**1.43****	1.35	1.50
		Male	60.6	105	**1.72****	1.57	1.88
		Female	52.7	68.4	1.29	1.22	1.37

≠ Geometric mean * p<0.05; ** p<0.001

Table 7.2 Intakes of food energy (MJ/kg/d) and macronutrients (g/kg/d) and changes in intakes between ages 11-12 and 16-18 years.

			Mean intake		**Change in intake (16-18 years -11-12 years)**		
	Units	Sample	11-12 years	16-18 years	Mean difference	Lower CI	Upper CI
Food Energy	MJ/kg/d	All	0.182	0.158	**-0.024****	-0.032	-0.017
		Male	0.192	0.167	**-0.025****	-0.038	-0.012
		Female	0.176	0.153	**-0.024****	-0.033	-0.014
Fat	g/kg/d	All	1.74	1.51	**-0.23****	-0.31	-0.15
		Male	1.80	1.61	**-0.19***	-0.32	-0.06
		Female	1.71	1.46	**-0.25****	-0.36	-0.14
Carbohydrate	g/kg/d≠	All	5.70	4.66	**0.81****	0.77	0.85
		Male	6.00	4.75	**0.79****	0.72	0.85
		Female	5.55	4.61	**0.83****	0.78	0.87
Protein	g/kg/d≠	All	1.24	1.25	1.01	0.96	1.06
		Male	1.35	1.47	1.08	0.98	1.19
		Female	1.18	1.15	0.97	0.91	1.03

≠ Geometric mean * *p*<0.05; ***p*<0.001

Table 7.3 Intakes of macronutrients (%FEI) and changes in intakes between ages 11-12 and 16-18 years.

			Mean intake		**Change in intake (16-18 years -11-12 years)**		
	Units	Sample	11-12 years	16-18 years	Mean difference	Lower CI	Upper CI
Fat	% food energy	All	35.0	34.9	-0.12	-0.97	0.71
		Male	34.6	35.7	1.06	-0.20	2.31
		Female	35.2	34.4	-0.75	-1.85	0.35
Carbohydrate	% food energy	All	52.7	50.4	**-2.30****	-3.25	-1.34
		Male	52.8	48.1	**-4.70****	-6.22	-3.17
		Female	52.6	51.6	-1.03	-2.20	0.14
Protein	% food energy≠	All	12.1	14.3	**1.18****	1.13	1.22
		Male	12.6	15.7	**1.24****	1.15	1.33
		Female	11.9	13.7	**1.15****	1.10	1.20

≠ Geometric mean * *p*<0.05; ***p*<0.001

Table 7.4 Differences in absolute intake of food energy (MJ/d) and macronutrients (g/d) between males and females at ages 11-12 and 16-18 years

		Mean intake		**Difference in intakes (males-females)**		
Units	Age (Years)	Male	Female	Mean difference	Lower CI	Upper CI
Food Energy (MJ/d)	11-12	8.40	7.70	**0.68***	0.17	1.19
	16-18	11.7	8.80	**2.83****	2.00	3.66
Fat (g/d)	11-12	78.5	73.5	5.01	-0.64	10.7
	16-18	113	83.8	**28.9****	19.3	38.6
Carbohydrate (g/d≠)	11-12	269	247	**1.08***	1.01	1.16
	16-18	338	272	**1.24****	1.13	1.35
Protein (g/d≠)	11-12	60.6	52.7	**1.15****	1.07	1.23
	16-18	105	68.4	**1.53****	1.38	1.69

≠ Geometric mean * *p*<0.05; ***p*<0.001

Table 7.5 Differences in macronutrient intake (%FEI) between males and females at ages 11-12 and 16-18 years

		Mean intake		**Difference in intakes (males-females)**		
% Food Energy	Age (years)	Male	Female	Mean difference	Lower CI	Upper CI
Fat	11-12	34.6	35.2	-0.53	-1.68	0.63
	16-18	35.7	34.4	1.27	-0.42	2.98
Carbohydrate	11-12	52.8	52.6	0.13	-1.06	1.32
	16-18	48.1	51.6	**-3.53***	-5.51	-1.56
Protein≠	11-12	12.6	11.9	**1.06***	1.01	1.11
	16-18	15.7	13.7	**1.15****	1.06	1.23

≠ Geometric mean * *p*<0.05; ***p*<0.001

Table 7.6 Differences in food energy (MJ/kg/d) and macronutrient intake (g/kg/d) between males and females at ages 11-12 and 16-18 years

		Mean intake		Difference in intakes (males-females)		
Units	Age (years)	Male	Female	Mean difference	Lower CI	Upper CI
Food Energy MJ/kg/d	11-12	0.191	0.177	0.014	-0.001	0.031
	16-18	0.167	0.153	0.014	-0.002	0.031
Fat g/kg/d	11-12	1.80	1.71	0.099	-0.072	0.271
	16-18	1.61	1.46	0.164	-0.017	0.345
Carbohydrate g/kg/d≠	11-12	6.00	5.55	1.07	0.97	1.19
	16-18	4.75	4.61	1.02	0.92	1.15
Protein g/kg/d≠	11-12	1.35	1.18	**1.14***	1.03	1.26
	16-18	1.47	1.15	**1.27****	1.13	1.43

≠ Geometric mean * p<0.05; **p<0.001

7.1.1. Food energy intake (FEI)

Food energy intake (FEI) (MJ/d) of the whole sample increased (1.9 MJ/d) significantly (p<0.001) over time (Table 7.1). This increase was significant for both males and females (p<0.001) but the increase observed in males (3.3 MJ/d) was nearly 3 times that of females (1.2 MJ/d). Further investigation (Table 7.4) revealed that whilst the average FEI of males were significantly (p<0.05) greater (0.68 MJ/d) than females at age 11-12 years, this difference had increased significantly (2.83 MJ/d) (p<0.001) by the age of 16-18 years.

This difference was less apparent when participants' body mass (kg) was taken into account (Table 7.2). Average daily food energy intake per kg body weight had fallen significantly by -0.02 MJ/kg/d, in the sample as a whole and in both males

(-0.03 MJ/kg/d) and females (-0.02 MJ/kg/d) separately (all $p<0.001$). Between males and females there was no significant difference ($p>0.05$) in average intake (MJ/kg/d) at either age (Table 7.6).

7.1.2. Dietary fat intake

It can be seen from Table 7.1 that between ages 11-12 and 16-18 years fat intake (g/d) increased significantly ($p<0.001$) in the sample as a whole by 18.5 g/d. This increase was greater in males (34.2g/d; $p<0.05$) than females (10.3g/d; $p<0.001$). Subsequently, at age 16-18 years males consumed significantly ($p<0.001$) higher intakes of fat (28.9g/d more) than females (Table 7.4).

There was a significant ($p<0.001$) decrease in fat intake per unit body mass (g/kg/d) in both males and females (Table 7.2). On this basis males reported higher intakes of fat than females at both time points (age 11-12 and 16-18 years), but the gender difference was not significant at either age ($p>0.05$) (Table 7.6).

As a proportion of percent food energy intake (% FEI) the overall intake of fat fell slightly between age 11-12 and 16-18 years (Table 7.3) but this fall was not significant ($p>0.05$). Intakes of males increased (1% point) and intakes of females decreased (-0.75% point), but neither change was significant ($p>0.05$). At age 11-12 years intakes were slightly higher in females (35.1%) compared with males (34.6%). However this trend was reversed at age 16-18 years with females consuming 34.4% and males consuming 35.6% energy from fat (Table 7.5). There were no significant differences in % FEI from fat between sexes at age 11-12 (-0.53% point) or 16-18 years (+1.27% point) (both $p>0.05$) (Table 7.5).

7.1.3. Dietary carbohydrate intake

Carbohydrate intake (g/d) increased significantly ($p<0.001$) between age 11-12 and 16-18 years (Table 7.1). Mean intake increased by 38.6 g/d, however the increase observed in males (+69.1g/d) was somewhat greater than that of females (+24.7g/d). In contrast, intakes of carbohydrate (g/kg/d) fell significantly ($p<0.001$) (Table 7.2) over the same time period and there were no significant differences observed between intakes of males and females at either age ($p>0.05$) (Table 7.6).

The average percent of food energy intake (%FEI) derived from carbohydrate decreased significantly between age 11-12 and 16-18 years ($p<0.001$) (Table 7.3). Intakes of males fell significantly (-4.7% points; $p<0.001$) whilst little change was observed in intakes of females (-1% points; $p>0.05$). At age 11-12 years there was little difference in % FEI from carbohydrate between males (52.7%) and females (52.6%), however at age 16-18 years males consumed significantly less energy from carbohydrate (%FEI) than females (48% and 51% respectively) ($p<0.05$) (Table 7.5).

7.1.4. Dietary protein intake

For all participants and all units of expression (g/d, g/kg/d, %FEI) there was an increase in protein intake between ages 11-12 and 16-18 years (Table 7.1 to Table 7.3). However a non-significant ($p>0.05$) decrease in protein intake was observed in females when expressed per unit body weight (g/kg/d) (Table 7.2). On average males consumed more energy from protein than females at both time points but the difference was significantly greater at age 16-18 years ($p<0.001$) (Table 7.5).

Summary of Chapter 7.1

- Absolute intakes of food energy (MJ/d) and macronutrients (g/d) increased over time in the whole sample with greater increases observed in males than females.
- At age 16-18 years percent food energy (%FEI) from protein in both males and females increased whilst percent food energy (%FEI) from carbohydrate decreased. Intakes of percent food energy (%FEI) from fat increased in males and decreased in females.
- When intake was expressed per unit body weight, protein intake (g/kg/d) increased in males whilst a decrease was observed in females. Total food energy (MJ/kg/d), fat (g/kg/d) and carbohydrate (g/kg/d) decreased in both males and females.

7.2. Tracking of energy and macronutrient intake from age 11-12 to 16-18 years

The first section of this chapter (7.1) sought to identify changes in nutrient intake between age 11-12 years and age 16-18 years. The focus of this section is to determine the extent to which the characteristics of dietary intake in childhood continued into late adolescence and to quantify tracking of dietary intake.

In the first instance, Pearson correlation analyses were carried out to assess the relationship between nutrient intakes at age 11-12 years (2000) and the corresponding nutrient intakes at age 16-18 years (2006) and are illustrated in Figure 7.1 to Figure 7.4. Table 7.7 to Table 7.9 show the mean intake of participants at age 11-12 and 16-18 years, for all participants by gender. The correlation coefficient of relationship between intakes at each time point is shown as Pearson's R with the significance of difference from zero (*p* value) established using the t-test indicated by asterisk (*) and the percentage of variance explained by the r^2 value.

Tracking, defined as the maintenance of relative position in rank of behaviour over time (Kelder *et al.* 1994) (Chapter 2.5), was used to determine the extent to which dietary intake in childhood continued into late adolescence. Participants were grouped into quartiles of intake at age 11-12 years and at age 16-18 years. Range of intake in each quartile by gender at age 11-12 and 16-18 years are shown in Table 7.10 to Table 7.20. The percentage of participants maintaining quartile position was assessed using cross tabulation (Table 7.10 to Table 7.20) and is illustrated by group in Figure 7.5 to Figure 7.9. By chance alone 25% of participants would be expected to maintain quartile position. Therefore to investigate the probability (strength of agreement) beyond chance that a participant would remain in the same quartile between the two time points the Kappa (*k*) test was applied to the cross tabulated data (Table 7.21).

To identify any social disparities, tracking of participants' mean intakes by social group (refer to Chapter 4) at each stage (age 11-12 and 16-18 years) (Figure 7.10 and Figure 7.11) were explored using the Kruskal Wallis test.

The correlations between food energy intake (MJ/d) and macronutrient intake (g/d) at age 11-12 years and corresponding intakes at age 16-18 years were modest (r^2 <20%) though all correlations were significant (p<0.001) (Table 7.7). The relationship between intakes of food energy (MJ/d) was stronger in males (R =0.42; r^2=18%) than in females (R=0.36; r^2=13%). The correlations for fat intake (g/d) was greater in males (R=0.49) and explained 24% of the variance of fat intake (g/d) at age 16-18 years compared to R=0.30 and 9% in females. The correlations between carbohydrate and protein intake (g/d) at age 11-12 years and corresponding intakes at age 16-18 years were similar in males and females with the relationship for protein intake being slightly weaker in males (p<0.05) than females (p<0.001) (Table 7.7).

When energy and macronutrient intake were expressed by kg/body weight, the effect of intake at age 11-12 years on corresponding intakes at age 16-18 years was stronger (MJ/kg/d r^2>30%, g/kg/d r^2>20%). Likewise the correlation for fat intake (g/kg/d) was increased (Table 7.8) but as with absolute intakes (g/d) continued to be greater in males (R=0.60, r^2=36%) than females (R=0.51, r^2=26%). Carbohydrate and protein intake (g/kg/d) at age 11-12 years had a stronger effect on female intakes at age 16-18 years (R=0.61, r^2=37%; R=0.52, r^2=27% respectively) than that of males (R=0.49, r^2=24%; R=0.47, r^2=22% respectively) (Table 7.8).

As a percentage of food energy intake (%FEI) the effect of all macronutrient intakes at age 11-12 years on intakes of corresponding nutrients at age 16-18 years was small (Table 7.9). The greatest (albeit weak) effect was found on males intake of fat (%FEI) at age 11-12 years which explained 20% of the variance at age 16-18 years. While the relationship between the intakes of % FEI from fat and carbohydrate at age 11-12 and

16-18 years were sigificant in both males (both $p<0.001$) and females ($p<0.05$; $p<0.001$ respectively), for protein intake when expressed as %FEI the relationship was significant only in females ($p<0.001$)(Table 7.9).

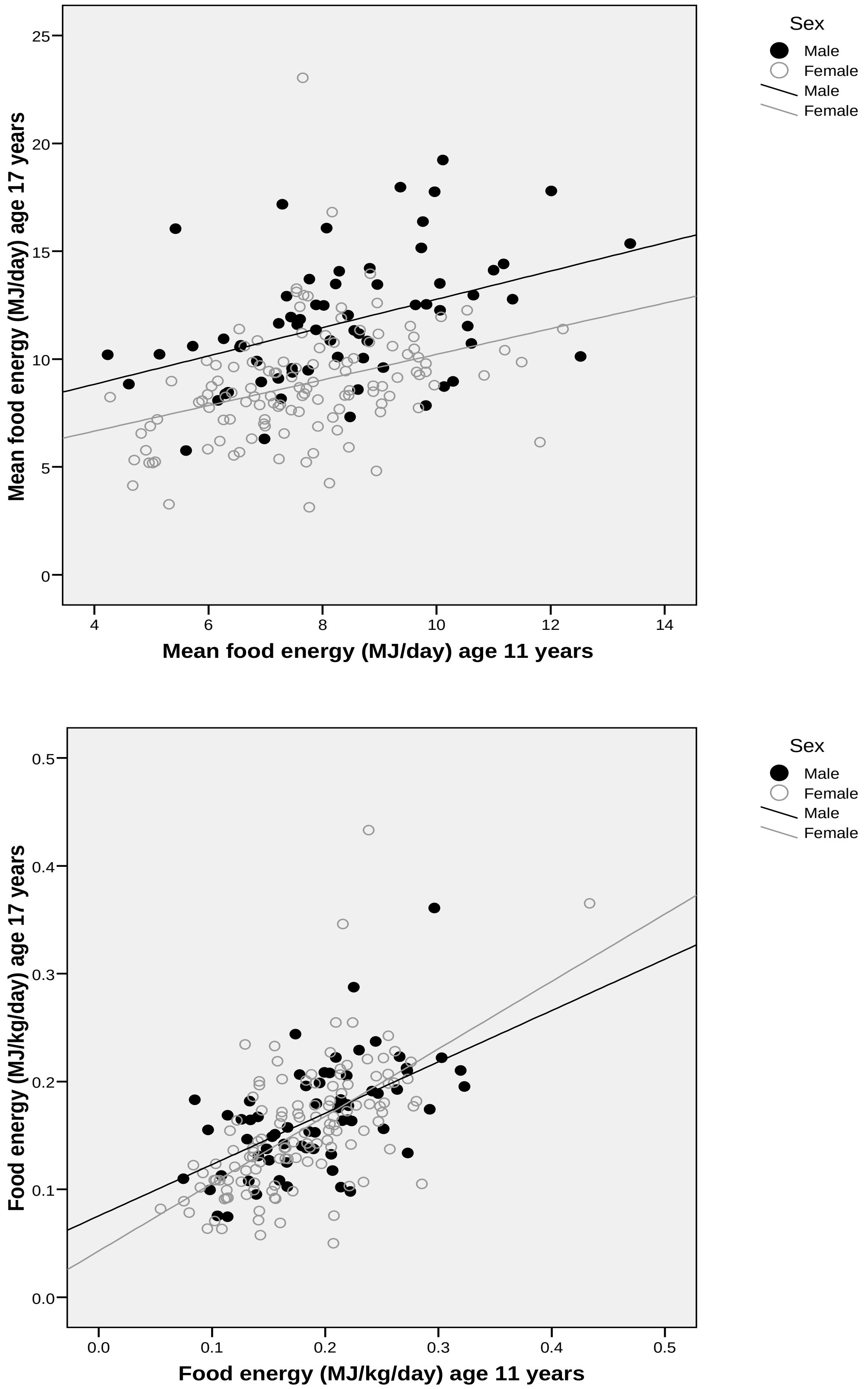

Figure 7.1 Pearson correlation graphs to illustrate associations between food energy intake (FEI) at age 11-12 years and at age 16-18 years

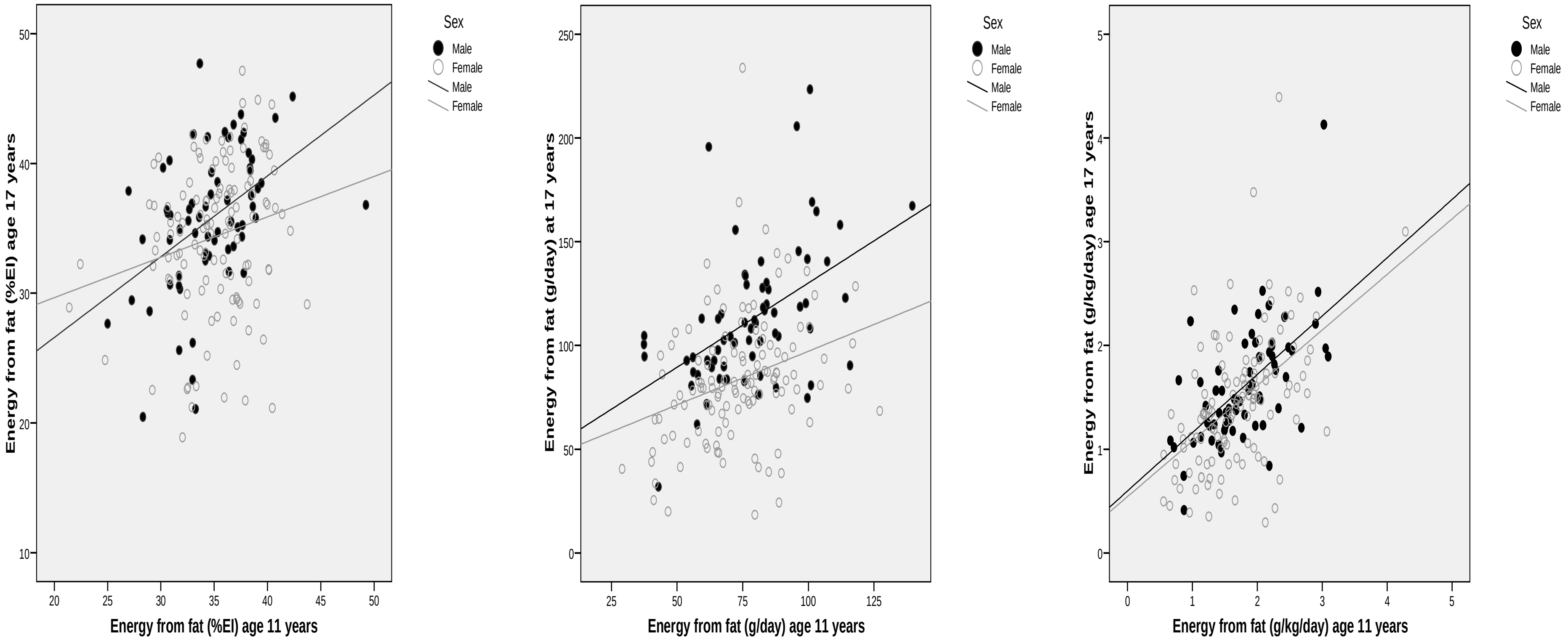

Figure 7.2 Pearson correlation graphs to illustrate associations between dietary fat intake at age 11-12 years and at age 16-18 years

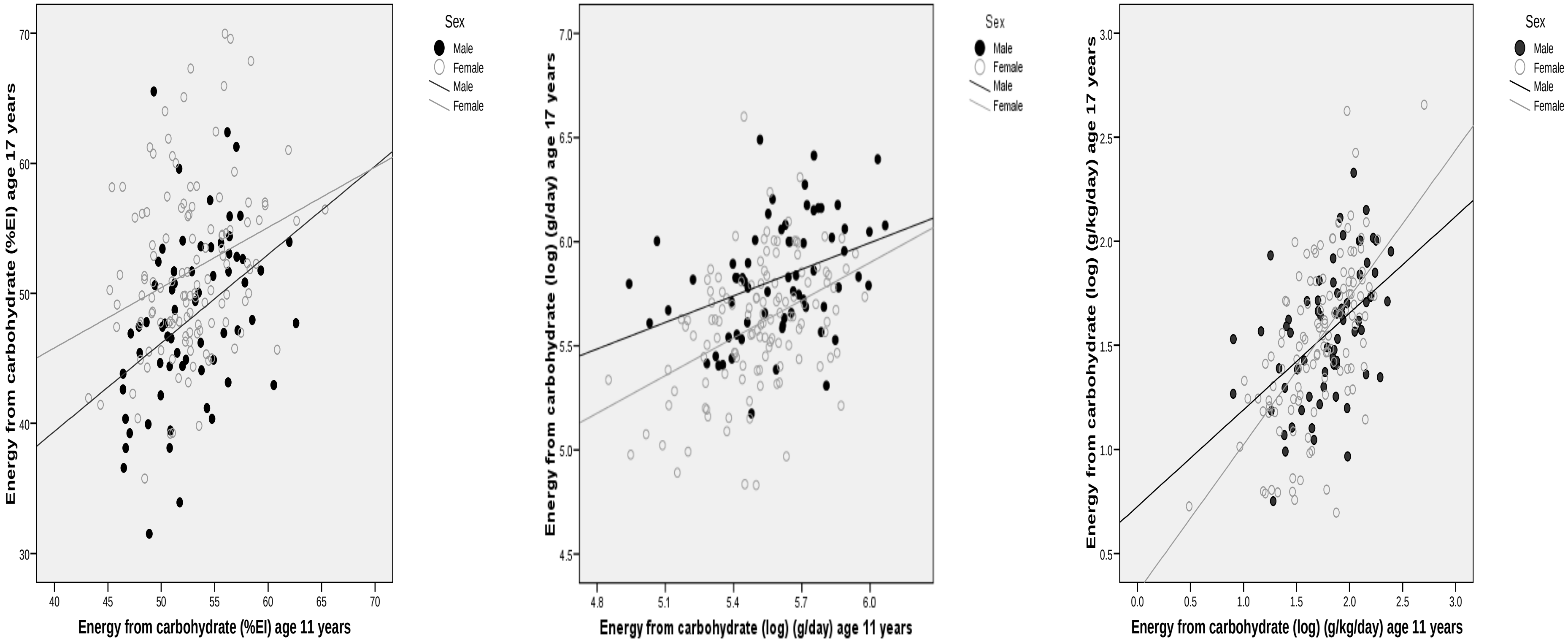

Figure 7.3 Pearson correlation graphs to illustrate associations between carbohydrate intake at age 11-12 years and at age 16-18 years

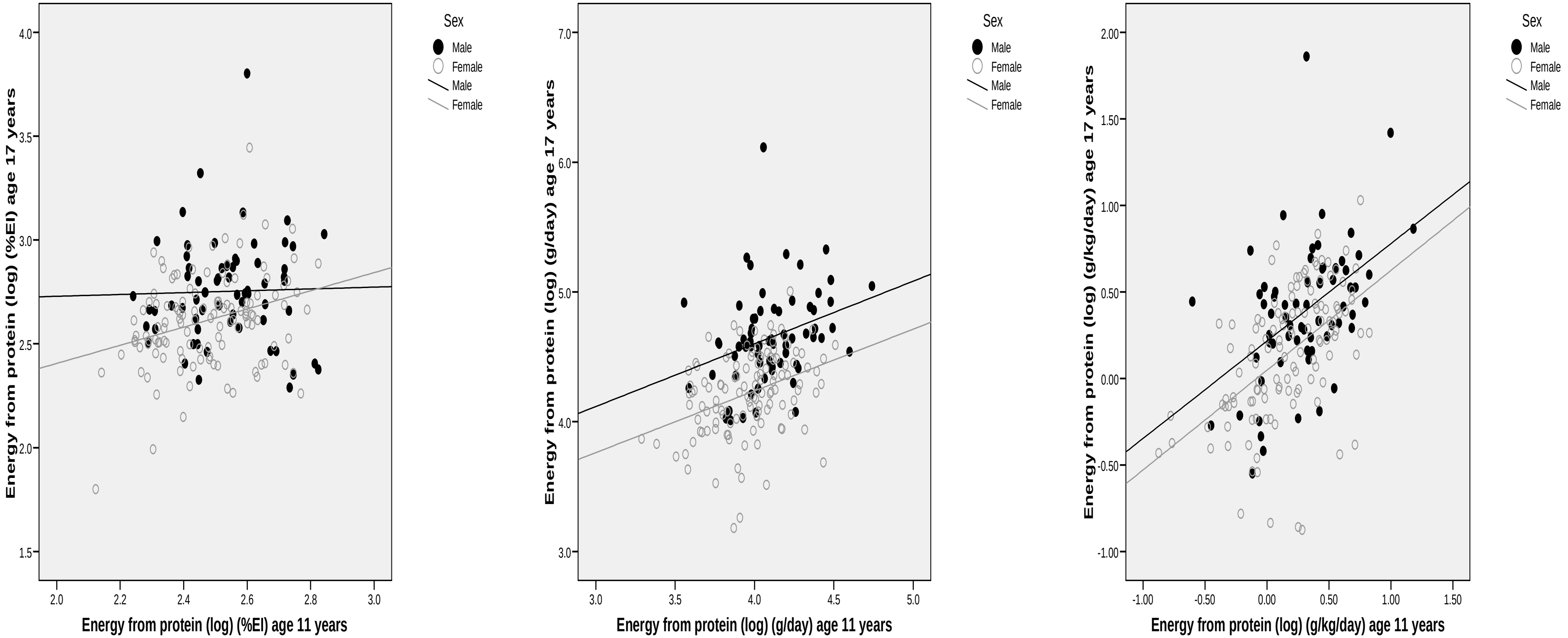

Figure 7.4 Pearson correlation graphs to illustrate associations between protein intake at age 11-12 years and at age 16-18 years

Table 7.7 The correlations between energy intake (MJ/d) and macronutrient intake (g/d) at age 11-12 years with corresponding intakes at age 16-18 years

			Mean intake		Correlation Coefficient	
	Units	Sample	11-12 years	16-18 years	Pearson R	% variance (r^2)
Food Energy	MJ/d	All	7.9	9.8	**0.42****	0.18
		Male	8.4	11.7	**0.42****	0.18
		Female	7.7	8.9	**0.36****	0.13
Fat	g/d	All	75.2	93.8	**0.39****	0.15
		Male	78.5	112.7	**0.49****	0.24
		Female	73.5	83.8	**0.30****	0.09
Carbohydrate	g/d≠	All	260.9	292.9	**0.43****	0.18
		Male	276.1	337.6	**0.37****	0.14
		Female	252.8	271.9	**0.42****	0.18
Protein	g/d≠	All	55.3	79.2	**0.42****	0.18
		Male	60.6	104.7	**0.31***	0.10
		Female	52.7	68.4	**0.36****	0.13

≠ Geometric mean * *p*<0.05; ***p*<0.001

Table 7.8 The correlations between energy intake (MJ/kg/d) and macronutrient intake (g/kg/d) at age 11-12 years with corresponding intakes at age 16-18 years

			Mean intake		Correlation Coefficient	
	Units	Sample	11 -12 years	16-18 years	Pearson R	% variance (r^2)
Food Energy	MJ/kg/d	All	0.18	0.16	**0.59****	0.35
		Male	0.19	0.16	**0.56****	0.31
		Female	0.18	0.15	**0.60****	0.36
Fat	g/kg/d	All	1.74	1.51	**0.54****	0.29
		Male	1.80	1.61	**0.60****	0.36
		Female	1.71	1.46	**0.51****	0.26
Carbohydrate	g/kg/d≠	All	5.70	4.66	**0.57****	0.32
		Male	6.00	4.75	**0.49****	0.24
		Female	5.55	4.61	**0.61****	0.37
Protein	g/kg/d≠	All	1.24	1.25	**0.53****	0.28
		Male	1.35	1.47	**0.47****	0.22
		Female	1.18	1.15	**0.52****	0.27

≠ Geometric mean * *p*<0.05; ***p*<0.001

Table 7.9 The correlations between percent energy intake (%FEI) derived from macronutrients at age 11-12 years on corresponding intakes at age 16-18 years

			Mean intake		Correlation Coefficient	
	Units	Sample	11-12 years	16-18 years	Pearson R	% variance (r^2)
Fat	% food energy	All	35.0	34.9	**0.28****	0.08
		Male	34.6	34.6	**0.45****	0.20
		Female	35.1	34.4	**0.20***	0.04
Carbohydrate	% food energy	All	52.7	50.4	**0.31****	0.10
		Male	52.8	48.1	**0.41****	0.17
		Female	52.6	51.6	**0.28****	0.08
Protein	% food energy≠	All	12.1	14.3	**0.24****	0.06
		Male	12.6	15.7	0.03	0.00
		Female	11.9	13.7	**0.30****	0.09

≠ Geometric mean * *p*<0.05; ***p*<0.001

7.2.1. Tracking of food energy intake (FEI)

Evidence of tracking was fairly strong in the lowest and highest quartiles of food energy intake (MJ/d) (Table 7.10 and Figure 7.5). Over 50% of both males (50%) and females (52%) maintained their position in the lowest quartile, and over 40% (44% males; 42% females) remained in the highest quartile. Tracking in the second and third quartiles was less evident, particularly in males, with less than 25% remaining in either quartile (12% and 18% respectively) (Table 7.10). Overall however, tracking of food energy intake (MJ/d) was poor at best (Table 7.21). A *k* of 0.16 for females and *k*=0.07 for males revealed that the probability that FEI (MJ/d) tracked between the two time points (age 11-12 and 16-18 years) was poor.

Table 7.10 Quartile of food energy intake (MJ/d) at age 16-18 years by quartile of intake (MJ/d) at age 11-12 years.

Quartile of intake (MJ/d) at age 11-12 years		Quartile group of food energy intake (MJ/d) at age 16-18 years		
	Range (MJ/d)	Gender	Range (MJ/d)	Maintenance of quartile position (%)
Lowest	<7.2	Male	<9.5	50
	<6.6	Female	<7.2	52
Second	7.2 to 8.3	Male	9.5 to 11.3	12
	6.6 to 7.7	Female	7.2 to 8.7	35
Third	8.3 to 9.8	Male	11.3 to 13.5	18
	7.7 to 8.8	Female	8.7 to 10.1	19
Highest	>9.8	Male	>13.5	44
	>8.8	Female	>10.1	42

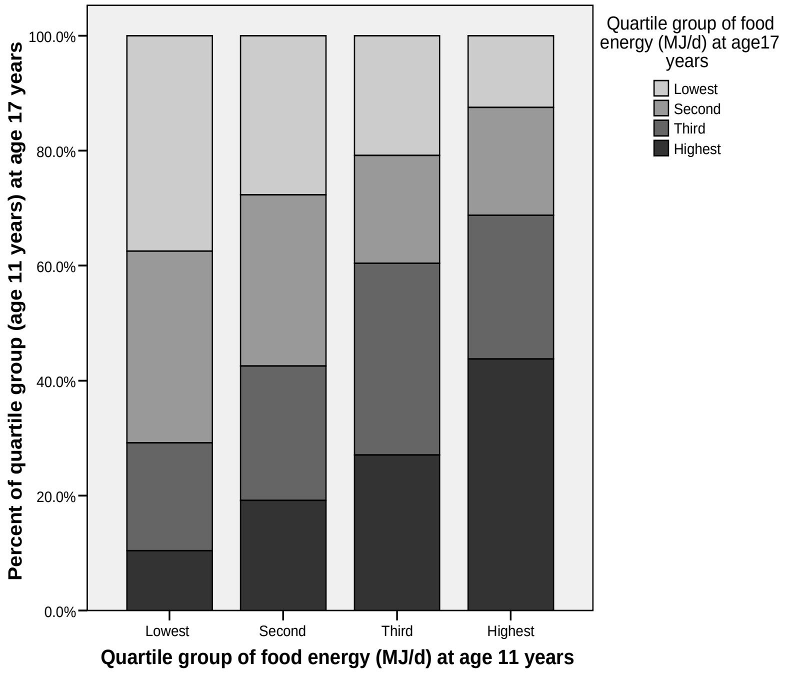

Figure 7.5 Percentage of participants maintaining relative quartile position (MJ/d) at age 16-18 years.

When body weight was taken into consideration (MJ/kg/d), on the whole, evidence of tracking in all participants increased (Figure 7.6). This is also illustrated by the significant (p<0.001) Pearson correlation (R=0.59 r^2=35%) in Table 7.8. Figure 7.6 shows that participants in the lowest quartile at age 11-12 years were less likely to move into the highest quartile at age 16-18 years (<5%), than the reverse scenario (<10%). Overall (lowest, second and highest quartiles), tracking of FEI (MJ/kg/d) was fair (Table 7.21) and slightly stronger in males (k=0.33) than females (k=0.24) (Table 7.11 and Table 7.21).

Table 7.11 Quartile of food energy intake (MJ/kg/d) at age 16-18 years by quartile of intake (MJ/kg/d) at age 11-12 years.

Quartile of intake (MJ/kg/d) at age 11-12 years		Quartile group of food energy intake (MJ/kg/d) at age 16-18 years		
	Range (MJ/kg/d)	Gender	Range (MJ/kg/d)	Maintenance of quartile Position (%)
Lowest	<0.15	Male	<0.13	50
	<0.14	Female	<0.11	48
Second	0.15 to 0.19	Male	0.13 to 0.16	59
	0.14 to 0.18	Female	0.11 to 0.15	32
Third	0.19 to 0.22	Male	0.16 to 0.20	35
	0.18 to 0.22	Female	0.15 to 0.19	41
Highest	>0.22	Male	>0.20	56
	>0.22	Female	>0.19	50

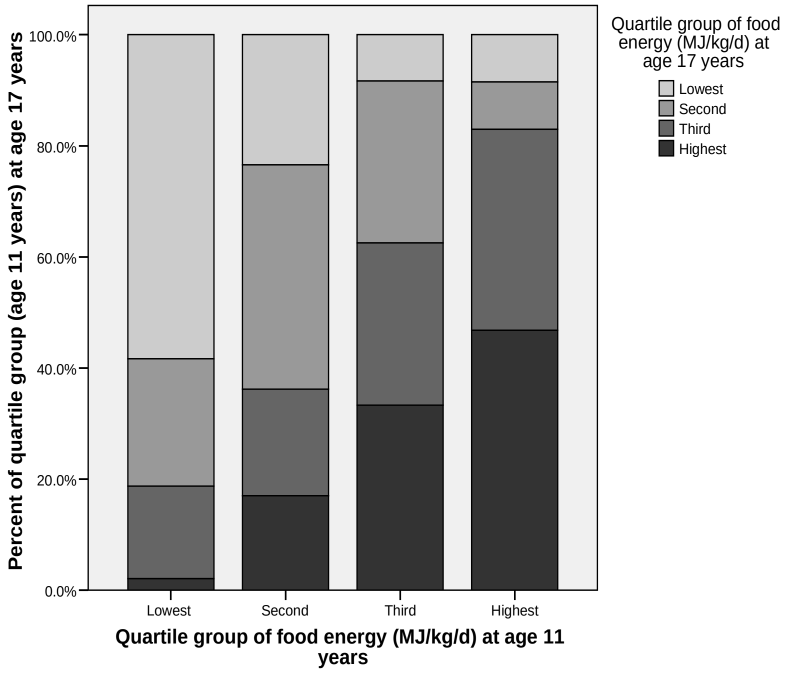

Figure 7.6 Percentage of participants maintaining relative quartile position (MJ/kg/d) at age 16-18 years.

7.2.2. Tracking of dietary fat intake

Tracking of dietary fat intake (%FEI) was poor (k=0.15 males, k=0.06 females) (Table 7.21). In the lowest quartile a greater percentage of males (50%) than females (26%) maintained position whilst maintenance of the highest quartile position was similar for both males (38%) and females (39%) (Table 7.12). When expressed as absolute units (g/d) tracking of fat intake was greater than as %FEI (Table 7.21). Overall, strength of agreement (k) was greater in males (k=0.25, p<0.001) than females (k=0.15, p<0.05) (Table 7.21), and males (56%) were more likely than females (32%) to maintain the upper 50th centile of fat intake (g/d) (Table 7.13). As with total food energy intake (MJ/kg/d), in the study participants as a whole, stability of position for dietary fat intake was greater when expressed per unit body weight (g/kg/d), with over 40% maintaining position in each quartile (Figure 7.7). Tracking was similar for both males and females (Table 7.14) and there was fair strength of agreement (k=0.23 males, k=0.32 females) (Table 7.21).

Table 7.12 Quartile of % FEI from fat at age 16-18 years by quartile of intake at age 11-12 years

Quartile of intake (%FEI) At age 11-12 years		Quartile group of fat intake/day (%FEI) at age 16-18 years		
	Range (%FEI/day)	Gender	Range (%FEI/day)	Maintenance of quartile Position (%)
Lowest	<31.8	Male	<33.0	50
	<32.8	Female	<31.0	26
Second	31.8 to 34.5	Male	33.0 to 36.0	35
	32.8 to 35.5	Female	31.0 to 35.3	26
Third	34.5 to 37.6	Male	36.0 to 39.5	24
	35.5 to 37.7	Female	35.3 to 38.2	28
Highest	>37.6	Male	>39.5	38
	>37.7	Female	>38.2	39

Table 7.13 Quartile of fat intake (g/d) at age 16-18 years by quartile of intake (g/d) at age 11-12 years

Quartile of intake (g/d) At age 11-12 years		Quartile group of fat intake (g/d) at age 16-18 years		
	Range (g/d)	Gender	Range (g/d)	Maintenance of quartile position (%)
Lowest	<65.2	Male	<90.2	44
	<61.5	Female	<67.5	48
Second	65.2 to 78.4	Male	90.2 to 107.0	29
	61.5 to 74.1	Female	67.5 to 82.0	32
Third	78.4 to 90.3	Male	107.0 to 128.2	47
	74.1 to 85.3	Female	82.0 to 98.8	31
Highest	>90.3	Male	>128.2	56
	>85.3	Female	>98.8	32

Table 7.14 Quartile of fat intake (g/kg/d) at age 16-18 years by quartile of intake (g/kg/d) at age 11-12 years

Quartile of intake (g/kg/d) At age 11-12 years		Quartile group of fat intake (g/kg/d) at age 16-18 years		
	Range (g/kg/d)	Gender	Range (g/kg/d)	Maintenance of quartile position (%)
Lowest	<1.39	Male	<1.23	44
	<1.25	Female	<1.02	52
Second	1.39 to 1.79	Male	1.23 to 1.54	47
	1.25 to 1.68	Female	1.02 to 1.42	42
Third	1.79 to 2.19	Male	1.54 to 1.96	29
	1.68 to 2.09	Female	1.42 to 1.74	50
Highest	>2.19	Male	>1.96	50
	>2.09	Female	>1.74	53

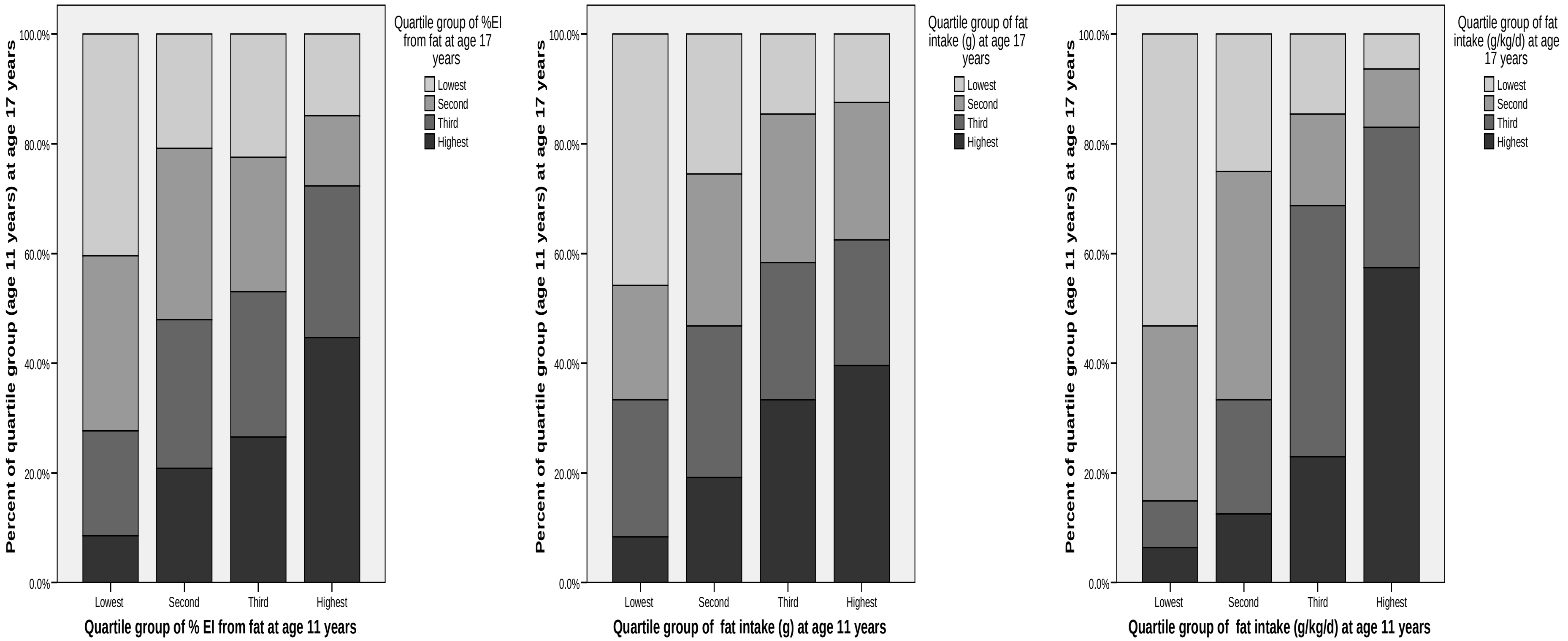

Figure 7.7 Percentage of participants maintaining relative quartile position of dietary fat intake at age 16-18 years (%FEI, g/d, g/kg/d)

7.2.3. Tracking of dietary carbohydrate intake

Tracking of dietary carbohydrate (%FEI) was greater, albeit poor (k=0.19, p<0.05), in males than females (Table 7.21). In males, 50% of the lowest quartile and 44% of the highest quartile maintained position compared to 32% in each quartile respectively for females (Table 7.15). When expressed as g/d (<35%) and g/kg/day (<35%), stability of tracking for all participants was weaker in the second and third quartiles than the highest and lowest quartiles (Figure 7.8). Similar percentages of both males and females maintained the lowest (50% males; 45% females) and highest quartiles (44% males; 45% females) for carbohydrate intake (g/d) (Table 7.16). When body weight was taken into account (g/kg/d) maintenance of the lowest quartile position was greater in females (68% females; 50% males), whilst maintenance of the highest quartile position was greater in males (56% males; 47% females) (Table 7.17). Overall tracking of carbohydrate intake (g/d) was poor for both males (k=0.19) and females (k=0.16), and was fair (k=0.23 males, k=0.26 females) when body weight (g/kg/d) was taken into consideration.

Table 7.15 Quartile of % FEI from carbohydrate at age 16-18 years by quartile of intake at age 11-12 years

Quartile of intake (%FEI) at age 11-12 years		**Quartile group of carbohydrate intake/day (%FEI) at age 16-18 years**		
	Range (%FEI/day)	Gender	Range (%FEI/day)	Maintenance of quartile position (%)
Lowest	<49.9	Male	<44.0	50
	<49.9	Female	<48.6	32
Second	49.9 to 52.0	Male	44.0 to 47.7	41
	49.9 to 52.6	Female	48.6 to 50.5	32
Third	52.0 to 56.2	Male	47.7 to 52.7	24
	52.6 to 55.6	Female	50.5 to 56.0	19
Highest	>56.2	Male	>52.7	44
	>55.6	Female	>56.0	32

Table 7.16 Quartile of carbohydrate intake (g/d) at age 16-18 years by quartile of intake (g/d) at age 11-12 years

Quartile of intake (g/d) at age 11-12 years		**Quartile group of carbohydrate intake (g/d) at age 16-18 years**		
	Range (g/d)	Gender	Range (g/d)	Maintenance of quartile position (%)
Lowest	<228.2	Male	<273.5	50
	<213.5	Female	<224.2	45
Second	228.2 to 275.8	Male	273.5 to 334.6	29
	213.5 to 250.8	Female	224.2 to 277.5	26
Third	275.8 to 316.7	Male	334.6 to 414.3	35
	250.8 to 286.6	Female	277.5 to 331.8	31
Highest	>316.7	Male	>414.3	44
	>286.6	Female	>331.8	45

Table 7.17 Quartile of carbohydrate intake (g/kg/d) at age 16-18 years by quartile of intake (g/kg/d) at age 11-12 years

Quartile of intake (g/kg/d) at age 11-12 years		**Quartile group of carbohydrate intake (g/kg/d) At age 16-18 years**		
	Range (g/kg/d)	Gender	Range (g/kg/d)	Maintenance of quartile position (%)
Lowest	<4.79	Male	<3.80	50
	<4.43	Female	<3.53	68
Second	4.79 to 6.38	Male	3.80 to 4.81	29
	4.43 to 5.75	Female	3.53 to 4.69	32
Third	6.38 to 7.82	Male	4.81 to 5.84	35
	5.75 to 7.26	Female	4.69 to 6.03	31
Highest	>7.82	Male	>5.84	56
	>7.26	Female	>6.03	47

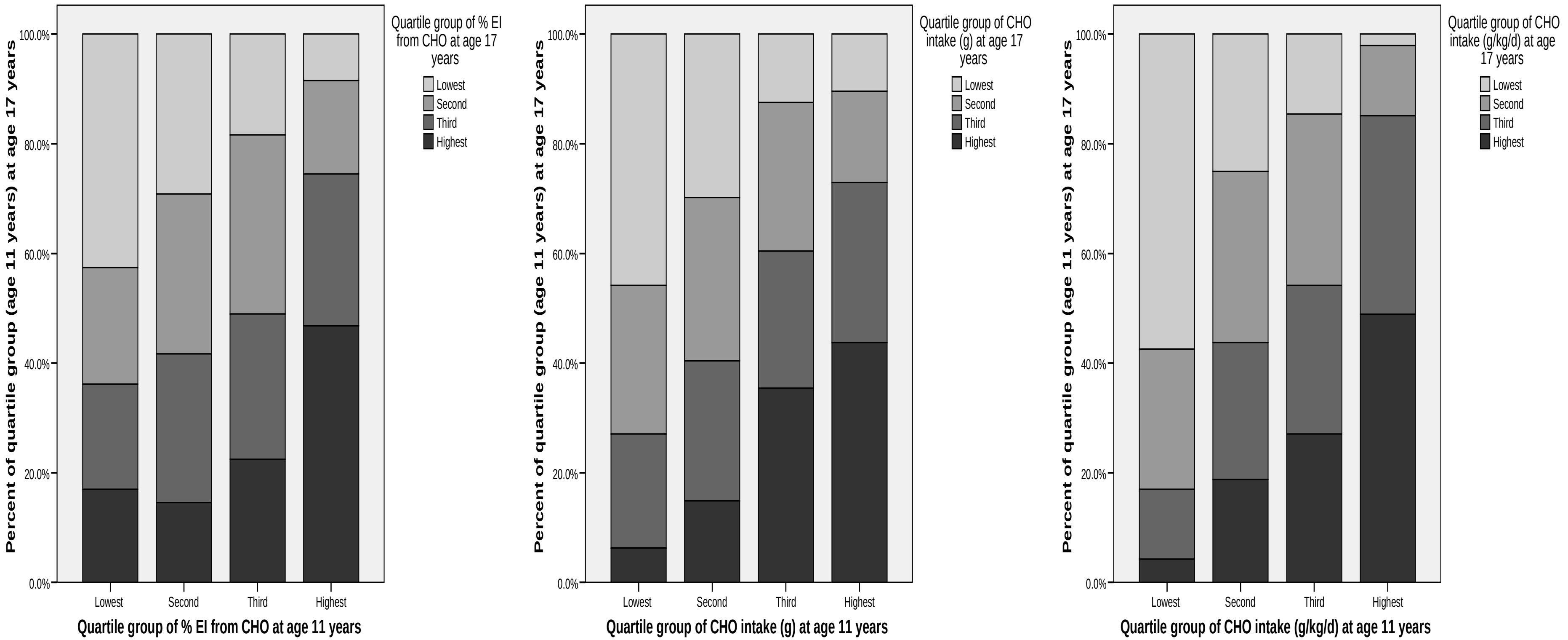

Figure 7.8 Percentage of participants maintaining relative quartile position of dietary carbohydrate intake at age 16-18 years (%FEI, g/d, g/kg/d)

7.2.4. Tracking of dietary protein intake

The weak correlation of protein intake (%FEI) at age 11-12 years and protein intake at age 16-18 years (Table 7.9) is illustrated further in Table 7.18 and Figure 7.9, with less than 35% of both males and females maintaining quartile position of %FEI (Table 7.18). The effect was stronger when protein intake was expressed as g/d (Table 7.10). Tracking was similar in males and females and strongest in the lowest (44% males; 42% females) and highest (44% males; 39% females) quartiles for both. As for the other macronutrients, evidence of tracking was stronger when body weight was taken into consideration (g/kg/d) (Table 7.11) with more than 60% (all participants) maintaining the lowest quartile position (Figure 7.9). Females (68%) were more likely than males (50%) to maintain the lowest quartile position, whilst similar figures were found for both males (44%) and females (43%) in the highest quartile (Table 7.20). Overall, for all units of expression (%FEI, g/d, g/kg/d) tracking of dietary protein intake was poor (Table 7.21).

Table 7.18 Quartile of % FEI from protein at age 16-18 years by quartile of intake at age 11-12 years

Quartile of intake (%FEI) at age 11-12 years		Quartile group of protein intake/day (%FEI) at age 16-18 years		
	Range (%FEI/day)	Gender	Range (%FEI/day	Maintenance of quartile position (%)
Lowest	<11.4	Male	<13.5	31
	<10.4	Female	<12.0	32
Second	11.4 to 12.7	Male	13.5 to 15.5	24
	10.4 to 11.9	Female	12.0 to 13.7	16
Third	12.7 to 14.2	Male	15.5 to 17.8	24
	11.9 to 13.4	Female	13.7 to 15.4	34
Highest	>14.2	Male	>17.8	25
	>13.4	Female	>15.4	32

Table 7.19 Quartile of protein intake (g/d) at age 16-18 years by quartile of intake (g/d) at age 11-12 years

Quartile of intake (g/d) at age 11-12 years		Quartile group of protein intake (g/d) at age 16-18 years		
	Range (g/d)	Gender	Range (g/d)	Maintenance of quartile position (%)
Lowest	<52.9	Male	<84.3	44
	<44.4	Female	<56.1	42
Second	52.9 to 59.0	Male	84.3 to 101.5	29
	44.4 to 54.3	Female	56.1 to 69.5	23
Third	59.0 to 70.8	Male	101.5 to 129.4	29
	54.3 to 61.5	Female	69.5 to 85.9	22
Highest	>70.8	Male	>129.4	44
	>61.5	Female	>85.9	39

Table 7.20 Quartile of protein intake (g/kg/d) at age 16-18 years by quartile of intake (g/kg/d) at age 11-12 years

Quartile of intake (g/kg/d) at age 11-12 years		Quartile group of protein intake (g/kg/d) at age 16-18 years		
	Range (g/kg/d)	Gender	Range (g/kg/d)	Maintenance of quartile position (%)
Lowest	<1.05	Male	<1.23	50
	<0.93	Female	<0.89	68
Second	1.05 to 1.39	Male	1.23 to 1.52	35
	0.93 to 1.22	Female	0.89 to 1.24	39
Third	1.39 to 1.71	Male	1.52 to 1.83	24
	1.22 to 1.54	Female	1.24 to 1.49	19
Highest	>1.71	Male	>1.83	44
	>1.54	Female	>1.49	43

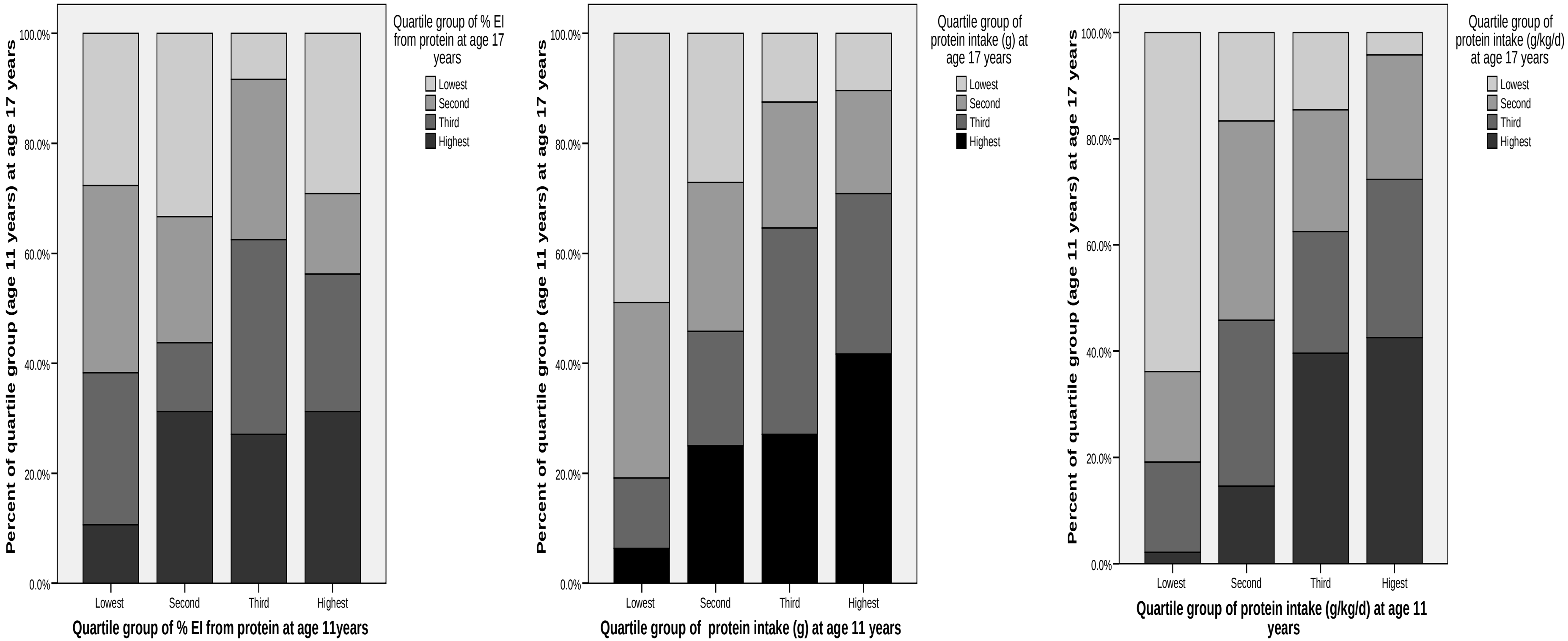

Figure 7.9 Percentage of participants maintaining relative quartile position of dietary protein intake at age 16-18 years (%FEI, g/d, g/kg/d)

Table 7.21 Strength of agreement (*kappa*) for maintenance of quartile position between age 11-12 years and age 16-18 years

	Males			Females		
	N	*k**	*p*	n	*k**	*p*
FEI (MJ/d)	66	0.07	0.32	125	**0.16**	**<0.001**
FEI (MJ/kg/d)	66	**0.33**	**<0.001**	124	**0.24**	**<0.001**
Fat %FEI	66	**0.15**	**<0.05**	125	0.06	0.24
Fat (g/d)	66	**0.25**	**<0.001**	125	**0.15**	**<0.05**
Fat (g/kg/d)	66	**0.23**	**<0.001**	124	**0.32**	**<0.001**
CHO %FEI	66	**0.19**	**<0.05**	125	0.05	0.33
CHO (g/d)	66	**0.19**	**<0.05**	125	**0.16**	**<0.05**
CHO (g/kg/d)	66	**0.23**	**<0.001**	124	**0.26**	**<0.001**
Protein % FEI	66	0.01	0.89	125	0.05	0.33
Protein (g/d)	66	**0.15**	**<0.05**	125	0.08	0.11
Protein (g/kg/d)	66	**0.17**	**<0.05**	124	**0.23**	**<0.001**

***Strength of agreement: value of *k* <0.20=Poor; 0.21-0.40=Fair; >0.41=Moderate**

7.2.5. Tracking of energy intake by social group

To identify social disparities in intakes of energy (MJ/d, MJ/Kg/d) or macronutrients (g/d, g/Kg/d, %FEI/d) mean intakes of each social group by gender were compared at each age using the Kruskal Wallis test. At age 11-12 years there were no significant differences between social groups (for males or females) for intakes of energy or macronutrients for any unit of expression. At age 16-18 years, in males only, participants from the low social group were more likely (p<0.01) to have higher intakes of fat (g/d, g/Kg/d) than those in the middle and high social groups (Figure 7.10 and Figure 7.11). There were no significant differences found for all other intakes of energy (MJ/d, MJ/Kg/d) or macronutrients (g/d, g/Kg/d, %FEI/d) at age 16-18 years.

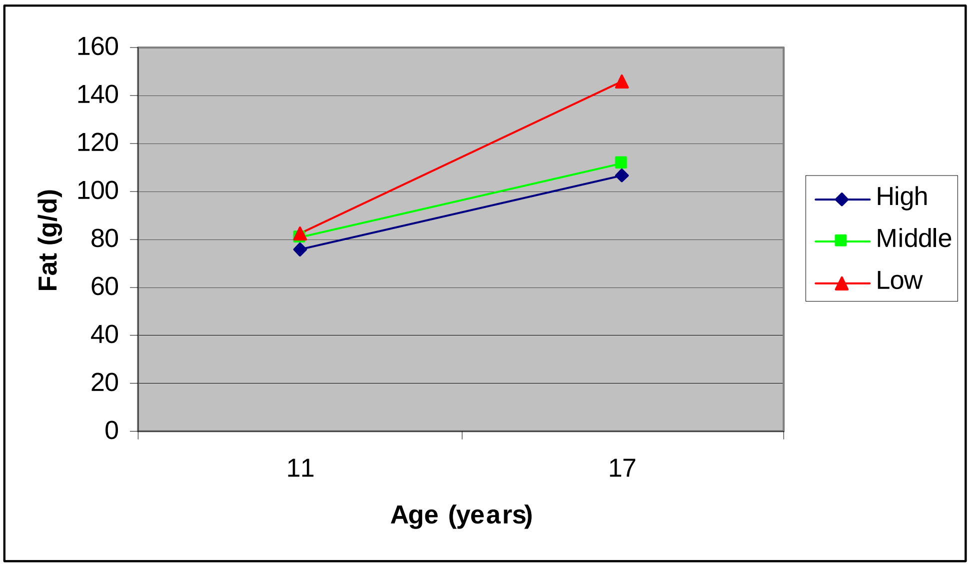

Figure 7.10 Tracking of fat intake (g/d) by social group (males)

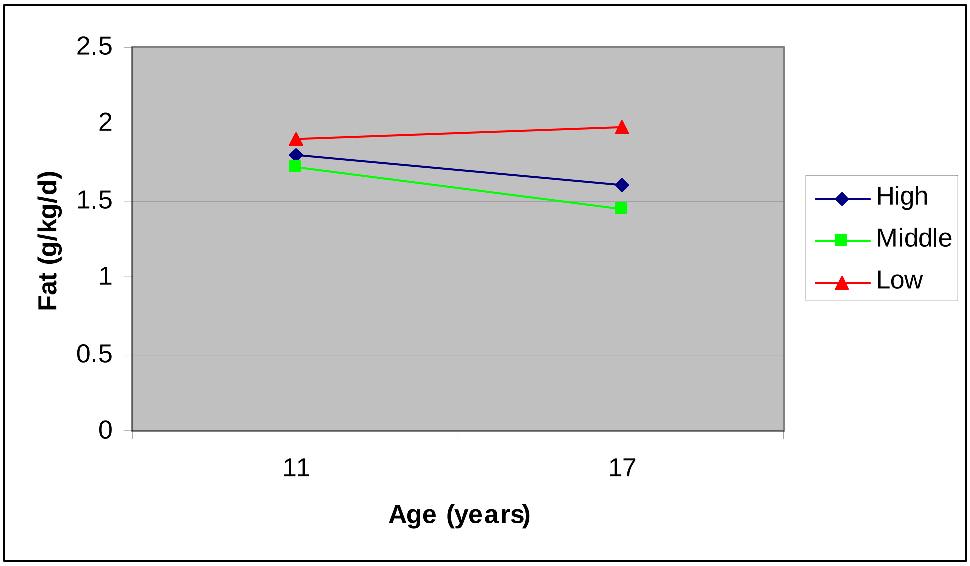

Figure 7.11 Tracking of fat intake (g/kg/d) by social group (males)

Summary of Chapter 7.2

- There were significant Pearson correlations between intakes (MJ/d; g/d; MJ/kg/d; g/kg/d) at age 11-12 years and intakes at age 16-18 years in both males and females but evidence of tracking (*k*) was poor.
- The strongest evidence of tracking was for total food energy intake when expressed relative to body weight (MJ/kg/d) in both males (*k*=0.33) and females (*k*=0.24).
- On the whole participants in the highest and lowest quartiles were most likely to maintain their relative position of rank of dietary behaviour.
- There was evidence of social disparity in intakes of fat (g/d, g/kg/d) for males but not females and only at age 16-18 years with males from the low social group consuming highest intakes at age 11-12 and 16-18 years.

7.3. <u>Discussion</u>

7.3.1. Change in dietary intake from age 11-12 years to 16-18 years

Few studies have explored the changes in dietary intake throughout adolescence (age 11-12 to 16-18 years) and those that have, are mainly cross-sectional in design rather than longitudinal (Nicklas *et al.* 2001; Alexy *et al.* 2002; Neumark Sztainer *et al.* 2003; Fletcher *et al.* 2004). There are few data therefore with which to directly compare results from the present study. Nevertheless it is interesting to explore how the changes reported in present study participants compare with longitudinal studies of other age groups (for example Singer *et al*. 1995; Post *et al*. 2001; Boreham *et al*. 2004; Craigie *et al.* 2004; Neumark Sztainer *et al*. 2004) (Figure 7.12 and Figure 7.13).

The primary focus of this chapter was to assess how nutrient intake from foods changed and tracked during the period of adolescence (Chapter 1). At age 16-18 years a large proportion of participants consumed alcohol which would have contributed to their total energy intake (Chapter 4.2.3). However, to make direct comparisons between intakes at age 11-12 years and age 16-18 years, expressing macronutrient intake as a percentage of food energy controlled for variations in alcohol intake between the two time points. For example the data reported at age 16-18 years was adjusted by deducting alcohol (g/d) from total food energy intake (MJ/d) and all macronutrients were re-calculated as a (%EI) from food (%FEI).

At age 16-18 years both males and females reported an increase in food energy intake (MJ/d) which is in agreement with males from the Young Hearts Study who reported higher intakes (MJ/d) at age 15 years than at age 12 years (Robson *et al*. 2000). In contrast at age 22 years both males and females in the same study reported significantly lower intakes of energy (MJ/d; $P < 0.04$) than at age 15 years (Boreham *et al.* 2004). Contrasting findings in terms of dietary change have been reported. Post *et al.* (2001) reported increases in energy intake (MJ/d) until the age of 21 years and a decrease at age 33 years, whilst Craigie *et al.* (2004) reported decreased intake (MJ/d) in females but increased intake (MJ/d) in males at age 33 years when compared with energy intake at age 11-12 years.

Explanations for these differences can be postulated. Essentially all of the studies were carried for different lengths of time over different years and secular changes over time are inevitable. Also cultural differences a likely to be present. For example, while the present study and that reported by Craigie *et al.* (2004) are UK based studies, those reported by Robson *et al.* (2000) and Boreham *et al.* (2004) are studies of Northern Irish participants and the AGHALS study (Post *et al.* 2001) is an Amsterdam based study (Chapter 2.5.2). Additionally, the Young Hearts Study was in three phases YH1 (age 12 and 15 years) YH2 (YH1 at age 15 years) and YH3 (age 22 years). YH3 was a follow-up of two cohorts, i.e. participants who were age 15 years in YH1 and those who were age 15 years in YH2 (Boreham *et al.* 2004). Subsequently some of the participants studied in YH3 were not studied at age 12 years and therefore were not included in the data by Robson *et al.* (2000) which may account for the decrease in intakes reported at age 15 and age 22 years. A plausible explanation for the increase observed in the present study, is that the period between age 11-12 and 16-18 years is one of rapid growth and development and increases in energy intake are inevitable (Department of Health, 1991). Similarly at age 22 years changes in energy intakes (MJ/d) (Post *et al.* 2001; Boreham *et al.* 2004) may have been associated with the life course events occurring between age 16 and 22 years, such as the transition from education to employment, and moving out of the family home with friends or partners (Wills, 2005). The reductions in intake after this age may be due to the decreased energy demands and a reduction in physical activity levels (Craigie *et al.* 2004), a notion which might be investigated further in a follow-up study of these young people.

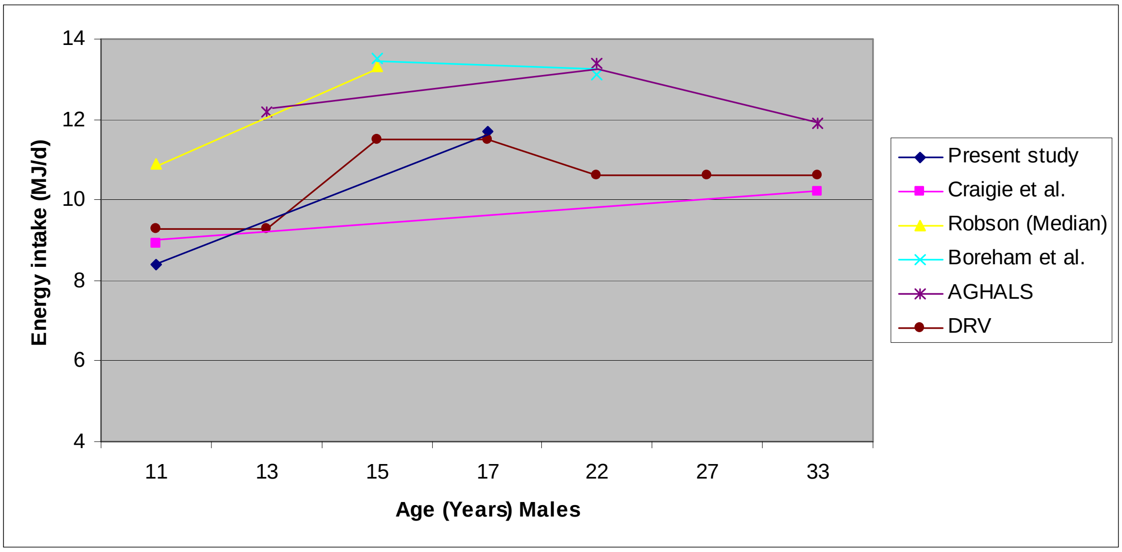

Figure 7.12 Energy intake (MJ/d) of present study participants (males) compared with other longitudinal studies

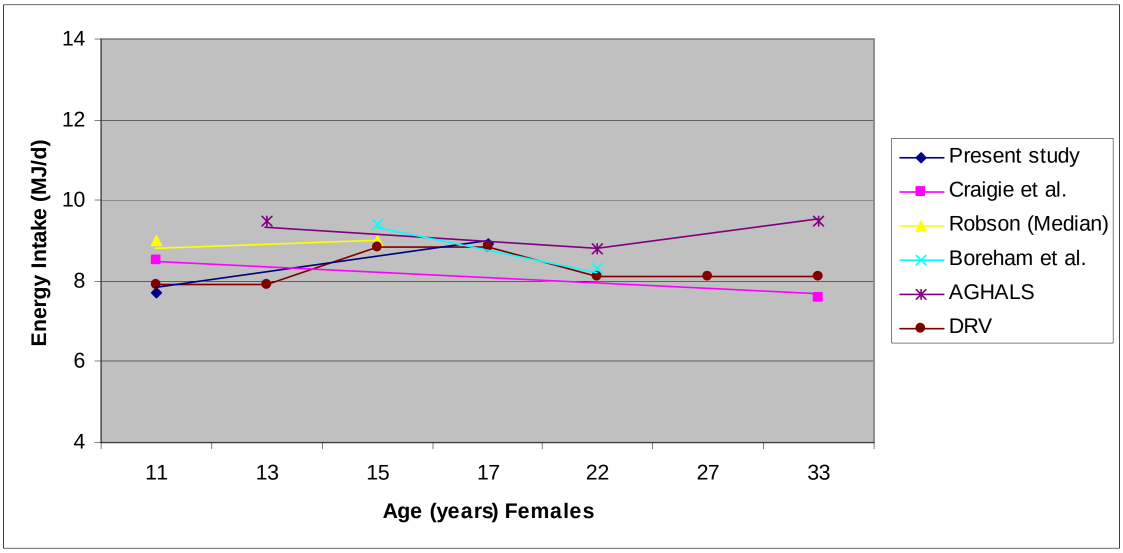

Figure 7.13 Energy intake (MJ/d) of present study participants (females) compared with other longitudinal studies

Whilst food energy was greater in males than in females at both age 11-12 and 16-18 years, the difference between the sexes increased over time (0.68MJ/d at 11-12 years; 2.83MJ/d at 16-18 years). This difference can be explained by the difference in body composition between males and females which increase as these young people approach physiological maturity (Chapter 2.2.1). Males were on average (12kg) heavier and (15cm) taller than females at 16-18 years (Chapter 4.4.2) and when body weight was accounted for (MJ/kg/d) there was no significant difference in food energy intake between males and females.

At age 16-18 years males reported significant increases in fat, carbohydrate and protein intake (g/d). Similar patterns were observed for females with the exception that an increase in protein intake was not significant. For both males and females intakes per kg body weight decreased between age 11-12 and 16-18 years. These findings were similar to those reported by Post *et al.* (2001) in which EI relative to body weight decreased until the age of 27 years in both males and females. This decrease continued in males at age 33 years whilst a slight increase was observed in females at age 33 years. The author also reported an increase in fat intake (g/d) in males until age 21 years and a decrease at age 33 years, but in females there was no significant change in fat intake (g/d) over the same period. Findings for protein intake were also similar, where males of both studies reported an increase over the study period.

Encouragingly, for both males and females there was little change in the average %FEI from fat which was around the recommended level of 35% at both ages (Department of Health 1991). Similarly Boreham *et al.* (2004) and Post *et al*. (2001) reported significant decrease in intakes of total fat (% energy P <0.001) to around the recommended level of 35% at age 15 and 22 years. This might suggest that health messages (Chapter 2.3) are not just simply understood but are being reflected in dietary behaviour. The small change in fat intake (%FEI) and a similar decrease in carbohydrate (%FEI) also reported by Boreham *et al.* (2004), was mirrored by an increase in percent energy from protein (%FEI). This decrease in %FEI from carbohydrate may be attributable to a decline in consumption of breakfast cereals and fruit and vegetables. For example authors have reported changes in food consumption patterns during adolescence (Lytle *et al.* 2000; Demory Luce *et al*. 2004; Videon & Manning, 2003). In a five year study of US children aged 8 to 14 years, Lytle *et al.* (2000) reported decreases in breakfast consumption, and particularly the variety of healthful foods consumed. Conversely, in a UK study of young people's food practices during the transition to adulthood, Wills (2005) found that young people reported an increase in breakfast consumption during this time (age 16-24 years).

Preoccupation with body weight and diet is also a common occurrence, especially in female adolescents (Barker *et al.* 2000) and the advent of 'protein diets' such as the Atkins diet (Atkins, 2003) may have influenced the intake of these participants, particularly females. In a UK study of adolescent females, Barker *et al.* (2000) found that girls who reported being less satisfied with weight were also more likely to report lower intakes of percentage energy from fat and higher percentage energy from protein (Chapter 2.3.1). This preoccupation with body image also occurs in males for example eating certain foods such as protein drinks (Chapter 4.2.3) to make them more muscular, or to gain or lose weight (Neumark-Sztainer *et al.* 1999).

Studies of adolescents have also shown that smoking is associated with reduced intakes of protein, carbohydrate, fruits and vegetables (Crawley & While, 1995), however in this study there were no significant differences found in dietary intake between smokers or non-smokers of either sex (Chapter 4.6).

As explained at the beginning of this discussion, at age 16-18 years, alcohol contributed to the energy consumption of more than 68% of these study participants (Chapter 4.2.3). However, it is noteworthy that although the difference in total energy intake is greater (2.6MJ/d (EI); 1.9MJ/d (FEI)) between age 11-12 years and age 16-18 years (1.9MJ/d) when alcohol is taken into consideration, the direction of change as %EI for all macronutrients is the same as for %FEI. For example, intakes of %EI from fat and carbohydrate also decreased in both males and females at age 16-18 years while protein intake in both males and females increased albeit to a slightly lesser extent when alcohol was included. Therefore this reduction in energy intake from fat (%EI) and carbohydrate (%EI) is not simply a reflection of increased protein intake, but also of the addition of alcohol to the diet of these study participants, the effects of alcohol consumption are discussed in Chapter 4.6.5.

It should also be considered in respect of changes seen between childhood and adolescence in the present study, and between other studies, that changes in intake may be attributable not only to change in food consumption. Methodological differences (Chapter 2.5.2) were also present between studies and are likely to contribute to variation in reported data. In the present study participants completed 2 x 3 day food diaries and were interviewed to clarify their content (Chapter 3.3), whilst Boreham *et al*. (2004) for example used the diet history method which is reliant on memory of usual diet and therefore is more susceptible to error. The different methods employed to measure portion size may also have introduced bias and mis-reporting of dietary intake should also be considered (Chapter 2.4 and Chapter 5.3).

7.3.2. Tracking of energy and macronutrient intake from age 11-12 to 16-18 years

There is evidence that dietary patterns formed in early life (Kelder *et al.* 1994; Singer *et al.* 1995; Wang *et al.* 2002) and in adolescence (Post *et al.* 2001; Craigie *et al.* 2004) may track into adulthood. However studies to date reporting the strength of tracking of diet during the adolescent years from childhood (age 11-12 years) to young adulthood (age 16-18 years) are scarce (Cusatis *et al.* 2000; Robson *et al.* 2000).

As reported by other authors (Cusatis *et al.* 2000; Robson *et al.* 2000; Post *et al.* 2001; Gallagher *et al.* 2005;) overall tracking of food energy and macronutrient intake in the present study was poor at best with less than 20% of the variance in intake at age 16-18 years explained by intake at age 11-12 years, and *kappa (k)* scores *(*Altman, 1991) of 0.16 for females and 0.07 for males. This contrasts with the much stronger tracking observed for body weight (Chapter 6). However in agreement with Dunn *et al.* (2000) and Craigie *et al.* (2004) there was a tendency to remain within the broad category of ranking with over 50% of those who were very low (MJ/d) or very high (MJ/d) consumers at age 11-12 years remaining to be as such at age 16-18 years.

As a percentage of total food energy intake (%FEI), evidence of tracking for macronutrients was also poor (*k*<0.20) in both males and females. Of particular note is the small percentage of females who maintained their position in the lowest quartile (26%) for fat intake (%FEI) suggesting that almost three quarters of the quartile increased their percentage energy from fat, which may be consistent with the notion that adolescents (age 16-18 years) eat an unhealthy, and in particular a high fat diet (Henderson *et al.* 2002; Larson *et al.* 2006). These findings were similar to those reported by Cusatis *et al.* (2000) in which females with the highest diet quality at age 12 years showed significant deterioration throughout adolescence. In agreement with Craigie *et al.* (2004) tracking of FEI and fat intake were stronger when expressed per unit body weight. The values for FEI (MJ/kg/d), which were fair (*k*=0.24 females) to moderate (*k*=0.33 males), were similar to data reported by Robson *et al.* (2000).

It is widely acknowledged that measurement of dietary intake is subject to methodological errors such as mis-reporting (Chapter 5.3). This may help explain the weaker tracking of nutrients compared with body size (height and weight) which can be measured with greater precision (Chapter 2.2.1). Furthermore methodological differences between dietary data collections, time period lapses between sampling periods and methods used for the calculation of tracking coefficients (Chapter 2.5) make it difficult to compare meaningfully the datasets (Gallagher *et al.* 2005).

In addition, changes that occur during adolescence are erratic and it might be intuitively assumed that in striving for greater autonomy, intakes at this age would be less likely to show evidence of tracking. In childhood, intakes are dictated by parental guidance and reporting of intakes may also be influenced by parents therefore increasing the probability of tracking at this younger age (Singer *et al.*1995). During adolescence societal influences become more influential and therefore change is more likely to occur over this time (Chapter 2.3.1).

It is also possible that as with BMI (Chapter 6) dietary behaviour in late adolescence may be more inclined to stabilise and persist into adulthood; however no studies to date have explored this notion and might be investigated further in a follow-up study of these participants. Furthermore it might be postulated, that if dietary intake does stabilise in late adolescence this would be a key time for preventative measures of unhealthful behaviours to be in place.

Social group effects on tracking of energy intake

Interestingly none of the studies discussed above reported any social group effects on the tracking of energy intake. In this study the only evidence of social disparity in tracking was in dietary intake of fat for male participants. In absolute terms (g/d) there was an increase in fat intake across all social groups but there was a significantly greater increase in participants from the low social group. This social disparity in fat intake continued to be evident when body weight (g/kg/d) was taken into consideration suggesting that the greater fat intake was not simply a reflection of greater increase in body mass. This disparity may in part be explained by the environments (Lake and Townshend*.* 2006) in which participants live and work. For example in lower socioeconomic areas there may be a greater number of food outlets where the availability of healthy choices are constrained, such as ‘pie shops’ and ‘fish and chip shops’. Education (or lack of) may also be a factor in the choices of these young males where health and nutrition is not a priority (Chapter 2.3).

8. MODELLING THE PREDICTION OF ADIPOSITY IN LATE ADOLESCENCE

Introduction

Obesity has come to be considered a global epidemic and excess body weight is now the most common childhood disorder in Europe (World Health Organization, 2003). However the aetiology of overweight and obesity is complex and multifaceted (Butland *et al.* 2007). Studies have reported a number of plausible contributory factors of obesity in children and adolescents but expert opinion is divided on the primary causal factor (World Health Organization, 2003b) (Chapter 2.2).

The previous chapters have described the participants of the present study in terms of their demographic characteristics, anthropometric measurements and health related behaviours at age 16-18 years (Chapter 4); compared the height, weight and BMI of study participants at age 16-18 years with those of the same individuals at age 11-12 years (Chapter 6); provided estimates of changes in, and tracking of, anthropometric measurements (focussed on overweight and obesity) between age 11-12 and 16-18 years (Chapter 6); compared the dietary intake from age 16-18 years with that of these young people at age 11-12 years (Chapter 7) and provided estimates of changes in, and tracking of, diet over this period of adolescence (Chapter 7). Each of these chapters also investigated the individual relationships between each variable with a primary focus on the contributory factors to adiposity at age 16-18 years.

The aim of this chapter is to enlarge on those findings and investigates the relationship between a combination of individual variables and anthropometric outcomes at age 16-18 years.

General linear modelling (Chapter 3.9.5) was used to explore the effect of each variable in turn (Figure 8.1). The remainder of this chapter describes the models which explain the largest proportion of the variation in adiposity at age 16-18 years.

8.1. Anthropometric outcome variables investigated

As discussed in previous chapters, BMI (kg/m^2) was used as a proxy measure of adiposity in the baseline study at age 11-12 years and consequently was the main measure of adiposity in this follow-up study at age 16-18 years (Chapter 8.3). Due to the health risks associated with the distribution of adiposity (Chapter 2.2) predictors of % body fat (Chapter 8.4), waist circumference (WC) (Chapter 8.5) and waist to hip ratio (WHR) (Chapter 8.6) at age 16-18 years were also investigated.

8.2. Factors tested as predictors of adiposity at age 16-18 years

The factors tested as predictors of adiposity at age 16-18 years were broadly categorised into variables measured at age 11-12 years and variables measured at age 16-18 years (Figure 8.1). Given the focus of this thesis is energy balance (Chapter 1), dietary intake and anthropometric variables at each age were the primary factors, with social group and lifestyle factors at age 16-18 years also considered. The following sections describe these variables in more detail.

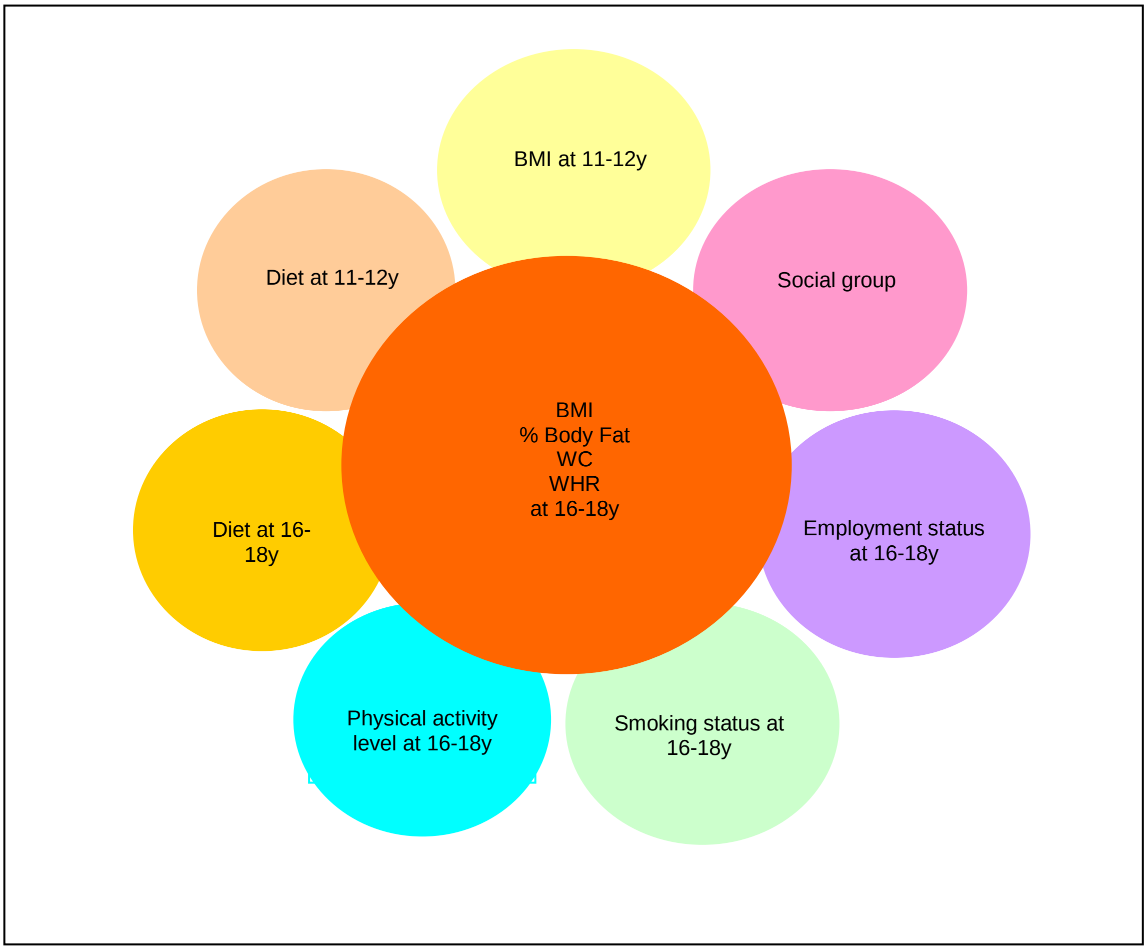

Figure 8.1 Variables tested as predictors of adiposity at age 16-18 years

8.2.1. Demographic factors

In the first instance, to investigate whether the predictors of adiposity at age 16-18 years differed between males and females, gender was tested as an interaction term with each factor (Appendix 11). A priori, following statistical advice, if more than half of the factors for each adiposity outcome were influenced by gender, then separate analyses were carried out for each gender. BMI was the only outcome found not to be influenced by gender, thus all outcome variables, other than BMI at age 16-18 years, were analysed separately by gender.

Social group was obtained by parental occupation at age 11-12 years (Chapter 3.2) and categorised into high, middle and low social groups (Fletcher *et al.,* 2004) for inclusion in these analyses. ‘Unclassified’ generally refers to participants for whom insufficient information was provided to enable classification (Chapter 3.2), for this reason participants from this group (n=12) were not included in these analyses. Education and/or employment status (Chapter 4.2.1) of participants were also included in the analyses.

8.2.2. Anthropometric factors

BMI was the only anthropometric measurement of adiposity at age 11-12 years and this was measured as the $\log_e$ of BMI (Chapter 4.2.2)at age 11-12 years. Chapter 6 discussed the relationship between BMI at age 11-12 years and BMI at age 16-18 years. The influence of BMI at age 11-12 years on all other measures of adiposity at age 16-18 years was also investigated (Chapter 6.1.3). This chapter investigates whether the strength of association remains when other variables are considered. The relationships (and health risks associated with) between each measure of adiposity at age 16-18 years have been discussed in Chapter 4.

8.2.3. Dietary intake

Diet and lifestyle factors are reported to be the primary reason for the high rates of excessive body fat (Willet, 1998). The key causes of the global increase in overweight and obesity have been identified as increased consumption of energy-dense foods high in fats and sugars, increased sedentary behaviour and reduced physical activity (Butland *et al.* 2007). Individual relationships between dietary intake at age 16-18 years and adiposity at age 16-18 years were discussed in Chapter 4. Chapter 7 described the influence of dietary intake at age 11-12 years on intake at age 16-18 years. This chapter describes the relationships between dietary intake at age 11-12 years and adiposity at age 16-18 years, and explores the extent to which intake of selected nutrients at both ages in combination might predict adiposity at age 16-18 years.

The nutrients tested were:

- Total energy intake (MJ) (with and without alcohol at age 16-18 years)
- Total fat (%EI)
- Total Carbohydrate (%EI)
- Protein (%EI)

8.2.4. Lifestyle

- Social group at age 11-12 years was tested in each model.

The lifestyle factors at age 16-18 years tested in the models were:

- Level of alcohol consumption
- Smoking behaviour
- Self reported physical activity
- Measured daily physical activity levels

Each of these variables are described in detail in Chapter 4.

8.2.5. Developing the models

The method used to produce a regression model for each outcome is discussed in Chapter 3.9.5. Briefly, each of the variables was investigated in turn. Where there were significant relationships, the most significant variable was considered as the primary variable. Each of the other variables was combined stepwise with the primary variable, to produce the most significant relationship. This sequence continued until all significant relationships were identified and no further influence was detected. Final models were produced based on the strongest relationships and are illustrated in Equation 8.1 to Equation 8.7 and Figure 8.1 to Figure 8.8[1].

[1] Shaded boxes represent the baseline variable set at 1. all other variables in that category take on values +/- regression coefficient x 1

8.3. Variables that most strongly predict BMI at age 16-18 years

Log_e BMI at age 16-18 years
= 0.942
+0.720(Log_e BMI at age 11-12 years)

- 0.026 if daily smoker
+ 0.006 if occasional smoker
+ 0.062 if used to smoke
if never smoked

+ 0.056 if unemployed
+ 0.063 if only work part time
+ 0.068 if work full time
+ 0.047 if at college
if in 6th form

Equation 8.1 Regression equation to predict log_e BMI at age 16-18 years

As discussed in Chapter 6 for both males and females, BMI at age 11-12 years was predictive of BMI at age 16-18 years. Given the strength of association (R=0.72) it was no surprise that this association remained when other factors were added to the model. Together with BMI at age 11-12 years, whether a person 'used to smoke' and if attending college or working was their primary occupation (Figure 8.2) explained 53% of the variation in BMI at age 16-18 years. No other factor added significantly to this model. In females only, EI at age 16-18 years was negatively associated with BMI at age 16-18 years (Chapter 4.3) however the predictive effect was lost when combined with BMI at age 11-12 years, indicating that the association may a result of under-reporting of dietary intake (Chapter 5.3) in females. Energy or nutrient intake at age 11-12 years was not significantly associated with BMI at age 16-18 years in either males or females. Alcohol intake of both males and females at age 16-18 years was positively and significantly associated with BMI at age 16-18 years (Chapter 4.3) however, there was no predictive effect when combined with other variables in the model. There were no significant association between any measures of physical activity and BMI at age 16-18 years (Chapter 4.4).

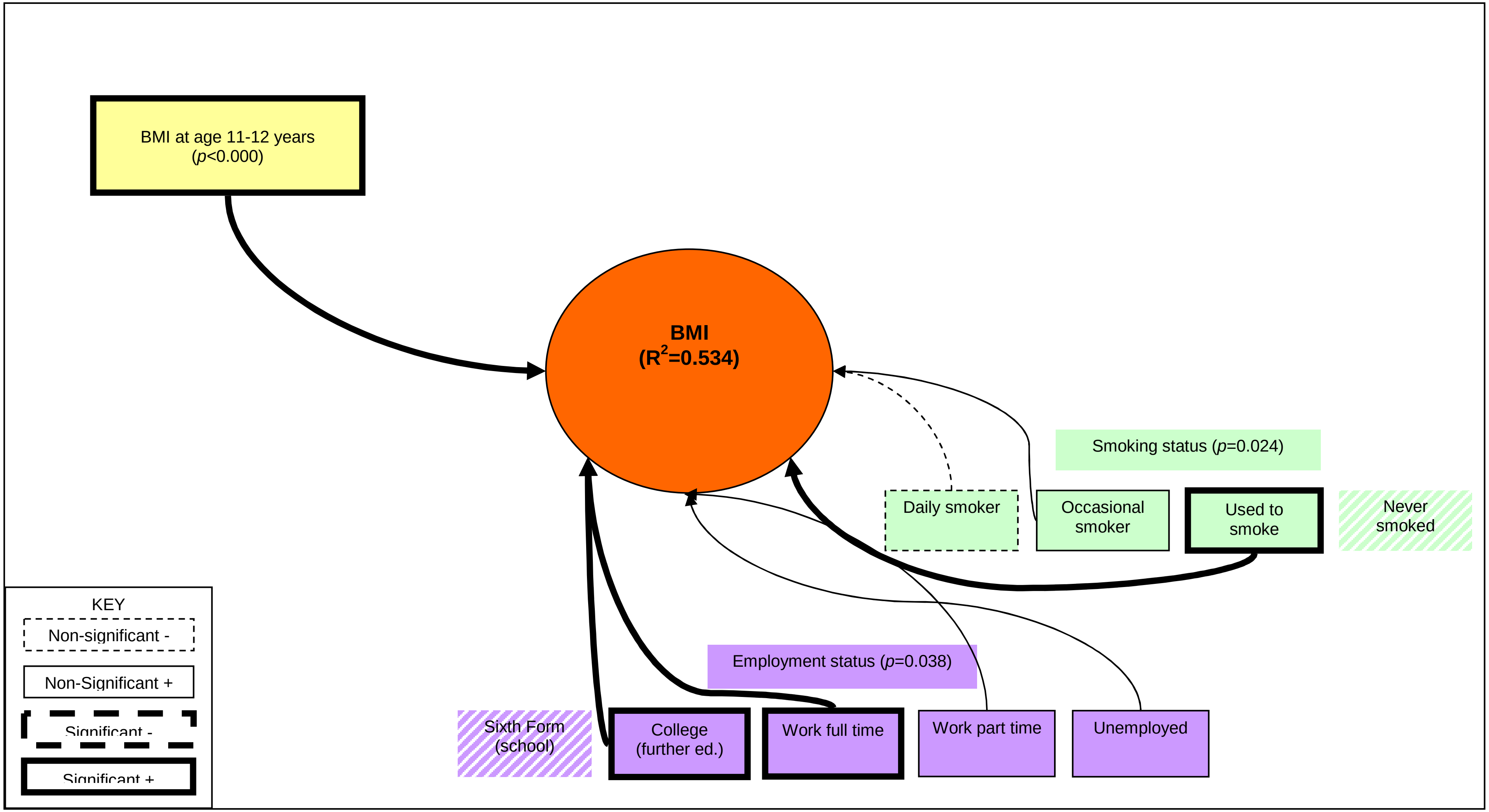

Figure 8.2 Variables found to most strongly predict BMI at age 16-18 years

8.4. Variables that most strongly predict % body fat at age 16-18 years

% Body Fat at age 16-18 years (male)
= -44.845
+ 18.713(Log_e BMI at age 11-12 years)

+ 5.830 if unemployed
+ 3.360 if in full time work
+ 3.205 if at college
(if at 6th form)

Equation 8.2 Regression equation to predict % body fat at age 16-18 years (males)

% Body Fat at age 16-18 years (female)
= - 99.005
+ 37.747(Log_e BMI at age 11-12 years)

+1.332 if daily smoker
- 0.654 if occasional smoker
+ 4.007 if used to smoke
If never smoked

+ 0.303 (%EI from fat at age 11-12 years*)*

Equation 8.3 Regression equation to predict % body fat at age 16-18 years (females)

Whilst there was a weaker association between BMI at age 11-12 years and % body fat at age 16-18 years (than of BMI at age 16-18 years) (Chapter 6.1.3), it too was the strongest predictor of % body fat in models for both males and females. In males 38% of the variance in % body fat at age 16-18 years was explained by BMI at age 11-12 years and education/employment status. In females' different factors to those of males contributed to the model. BMI at age 11-12 years, smoking status and % EI derived from fat at age 11-12 years collectively explained 48% of the variance in % body fat at age 16-18 years.

At age 16-18 years energy intake or energy composition (EI or % EI) by males was not found to be significantly associated with % body fat at age 16-18 years. Interestingly in females, intakes of fat (%EI) at age 16-18 years were negatively (p<0.05) associated with % body fat at age 16-18 years (Chapter 4.3) but this association was lost when other factors were taken into consideration and therefore this was not found to contribute to the final model (Equation 8.3). Energy intake or energy composition (EI or

%EI) at 11-12 years, of either males or females was not significantly associated with % body fat at age 16-18 years. However in females only, when combined with BMI at age 11-12 years, fat intake (as %EI) at age 11-12 years was found to be a significant (p<0.05) predictor of % body fat at age 16-18 years.

Smoking at age 16-18 years was also a significant (p<0.05) predictor of females % body fat at age 16-18 years when combined with BMI at age 11-12 years. However when both variables were added to the model at the same time, the effect of smoking at age 16-18 years became less significant (p=0.07). Nevertheless both fat intake (%EI) and smoking status have been included in the final model as the percentage variance explained was greater when combined.

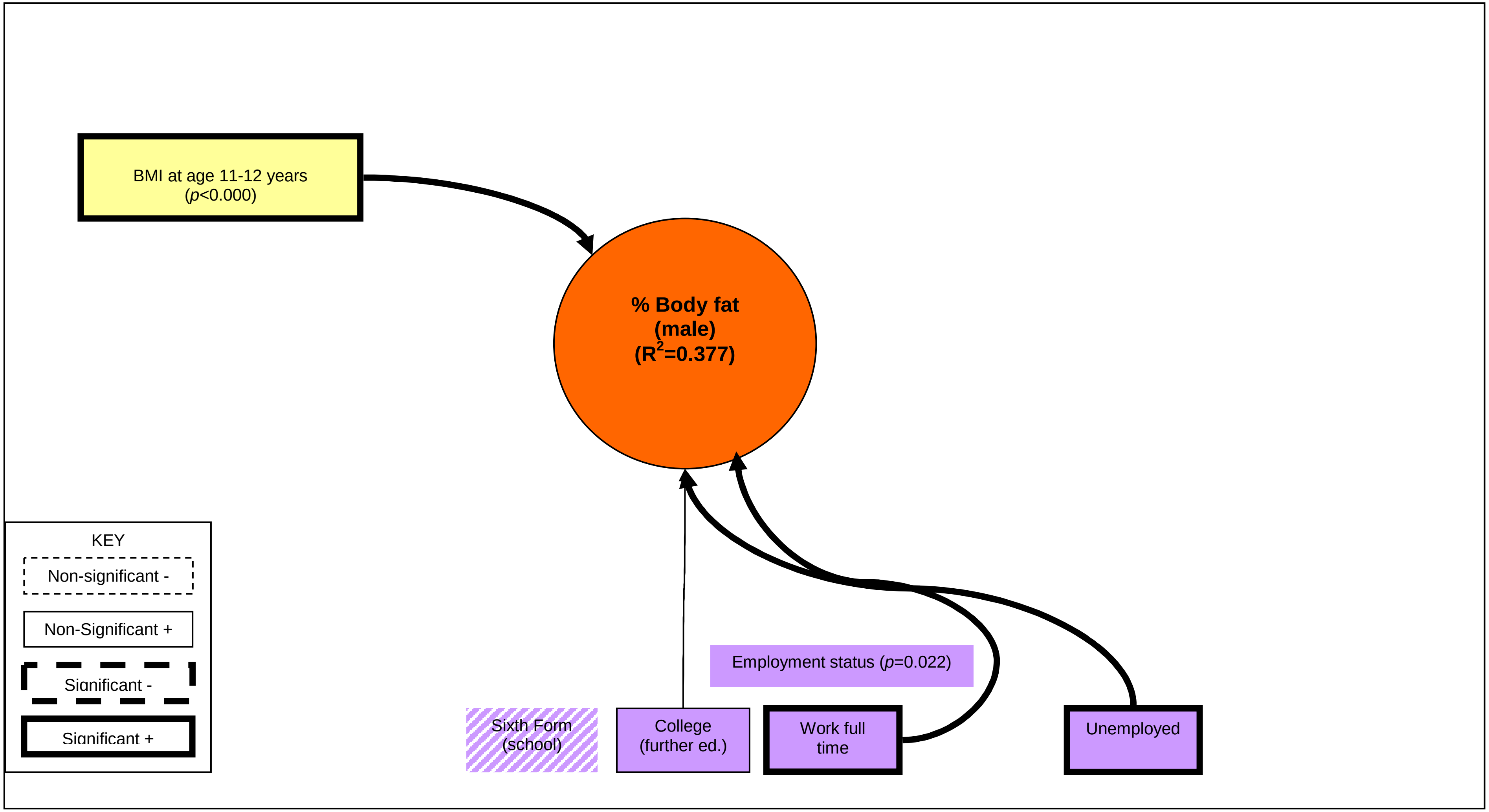

Figure 8.3 Variables found to most strongly predict % body fat at age 16-18 years (Males)

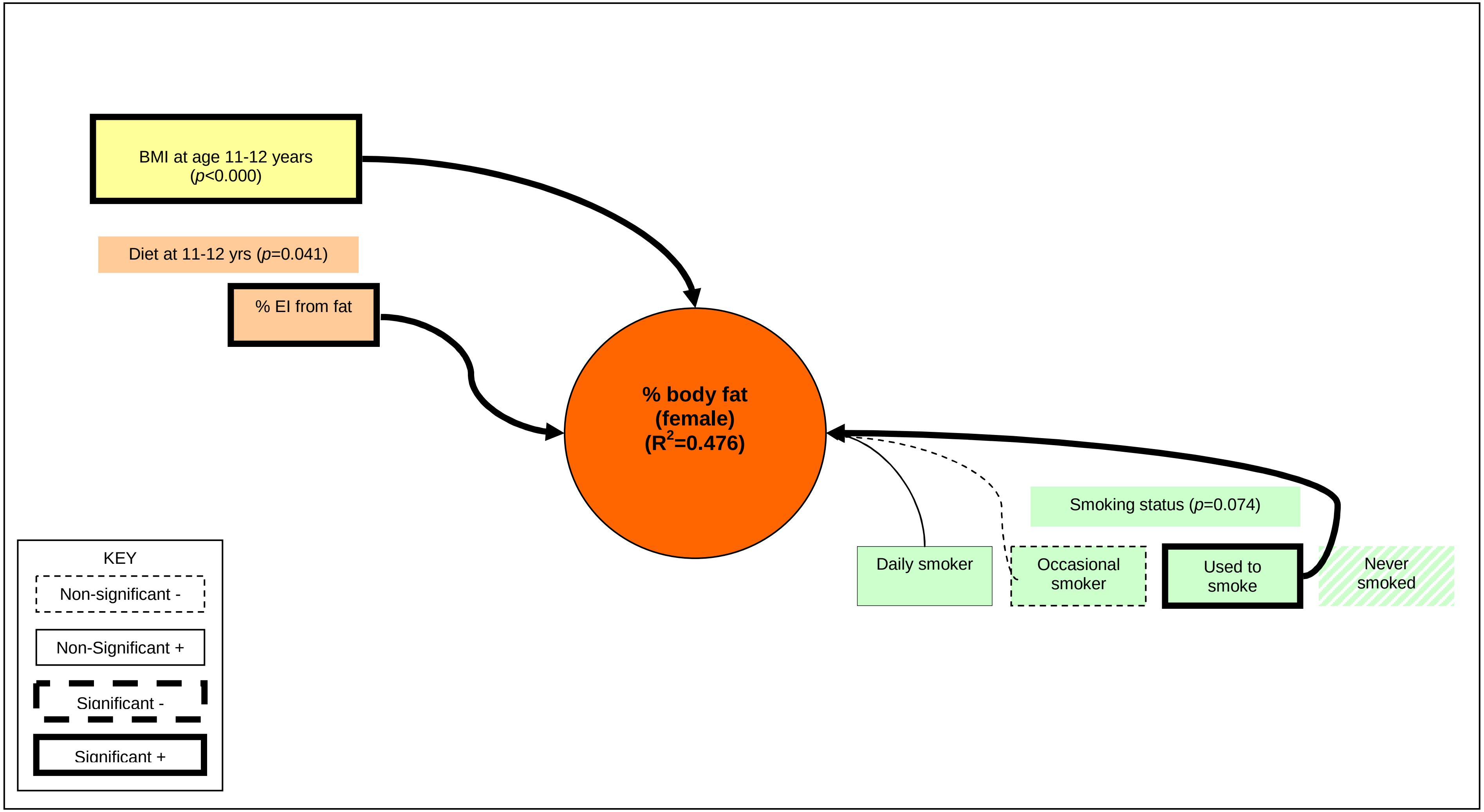

Figure 8.4 Variables found to most strongly predict % body fat at age 16-18 years (females)

8.5. Variables that most strongly predict waist circumference at age 16-18 years

Waist circumference at age 16-18 years (male)
= 3.315
+ 0.361(Log_e BMI at age 11-12 years)

- 0.065 if daily smoker
+ 0.143 if occasional smoker
+ 0.030 if used to smoke
if never smoked

+ 0.087 if unemployed
+ 0.038 if in full time work
+ 0.073 if at college
if at 6th form

Equation 8.4 Regression equation to predict waist circumference at age 16-18 years (males)

Waist circumference at age 16-18 years (female)
= 2.726
+ 0.524(Log_e BMI at age 11-12 years)

+ 0.022 If daily smoker
+ 0.015 if occasional smoker
+ 0.069 if used to smoke
if never smoked

- 0.044 if unemployed
+ 0.047 if in part time work
+ 0.058 if in full time work
+ 0.050 if at college
if at 6th form

- 0.003 if high alcohol consumed
+ 0.044 if low alcohol consumed
if no alcohol consumed

Equation 8.5 Regression equation to predict waist circumference at age 16-18 years (females)

Although separate models were produced for males and females, similar variables contributed to the final models for the prediction of WC at age 16-18 years. The strongest predictors of WC were similar to those of BMI and explained a comparable percent of the variance in WC (54% males, 50% females) as for BMI (53%). The relationships for each of the sexes were quite different however. In males the development of a high WC at age 16-18 years was most likely if they had a high BMI at age 11-12 years, were an occasional smoker (p=0.005) and unemployed at age 16-18 years (Figure 8.5). In contrast females were most likely to have a high WC at 16-18 years if they had a high BMI at age 11-12 years, used to smoke, were at college and were also low alcohol consumers (Figure 8.6). As with BMI at 16-18 years (Chapter 8.3) neither dietary intake at age 11-12 or 16-18 years, or physical activity contributed significantly to the models for the prediction of WC at age 16-18 years.

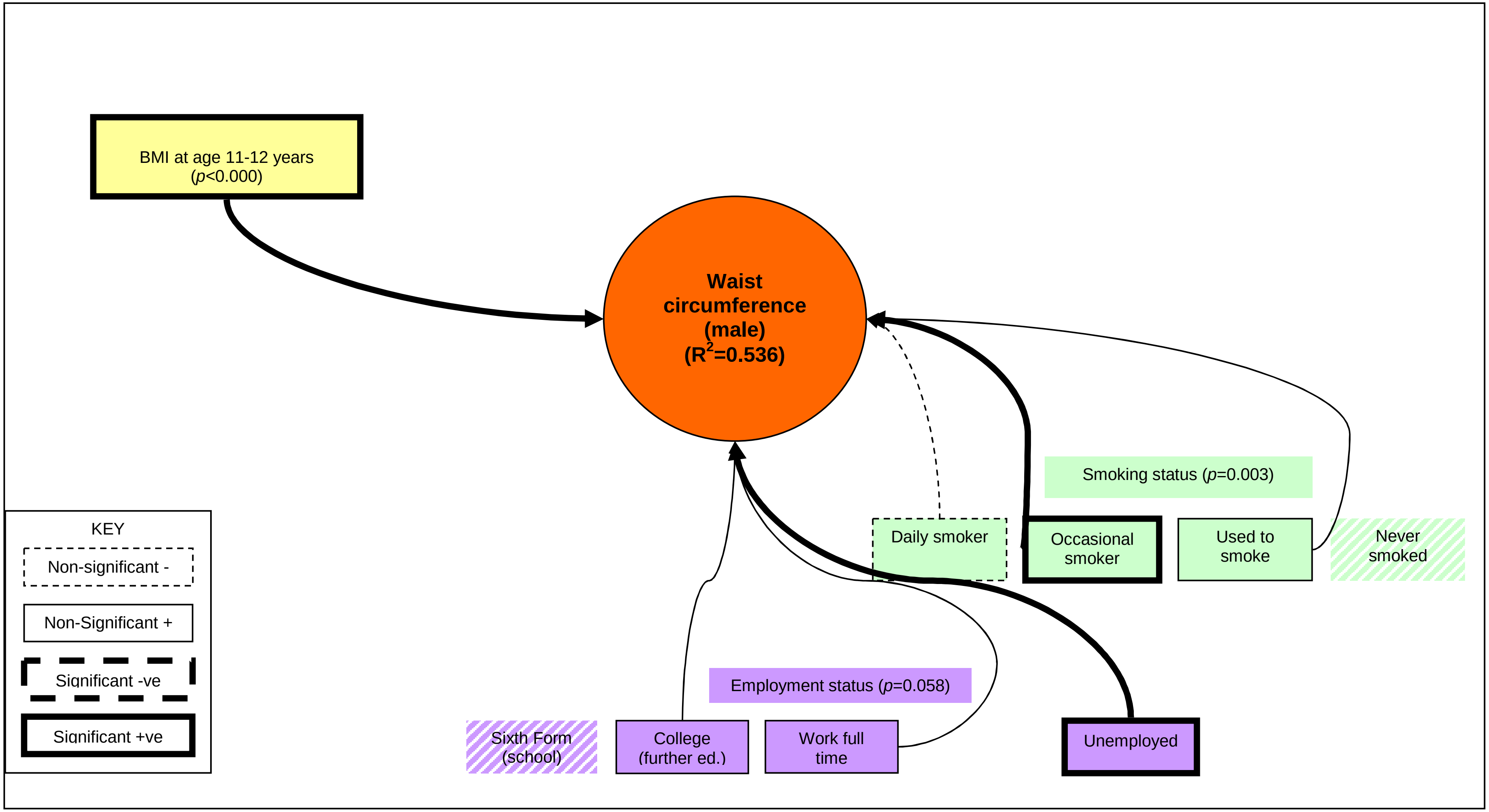

Figure 8.5 Variables found to most strongly predict waist circumference at age 16-18 years (males)

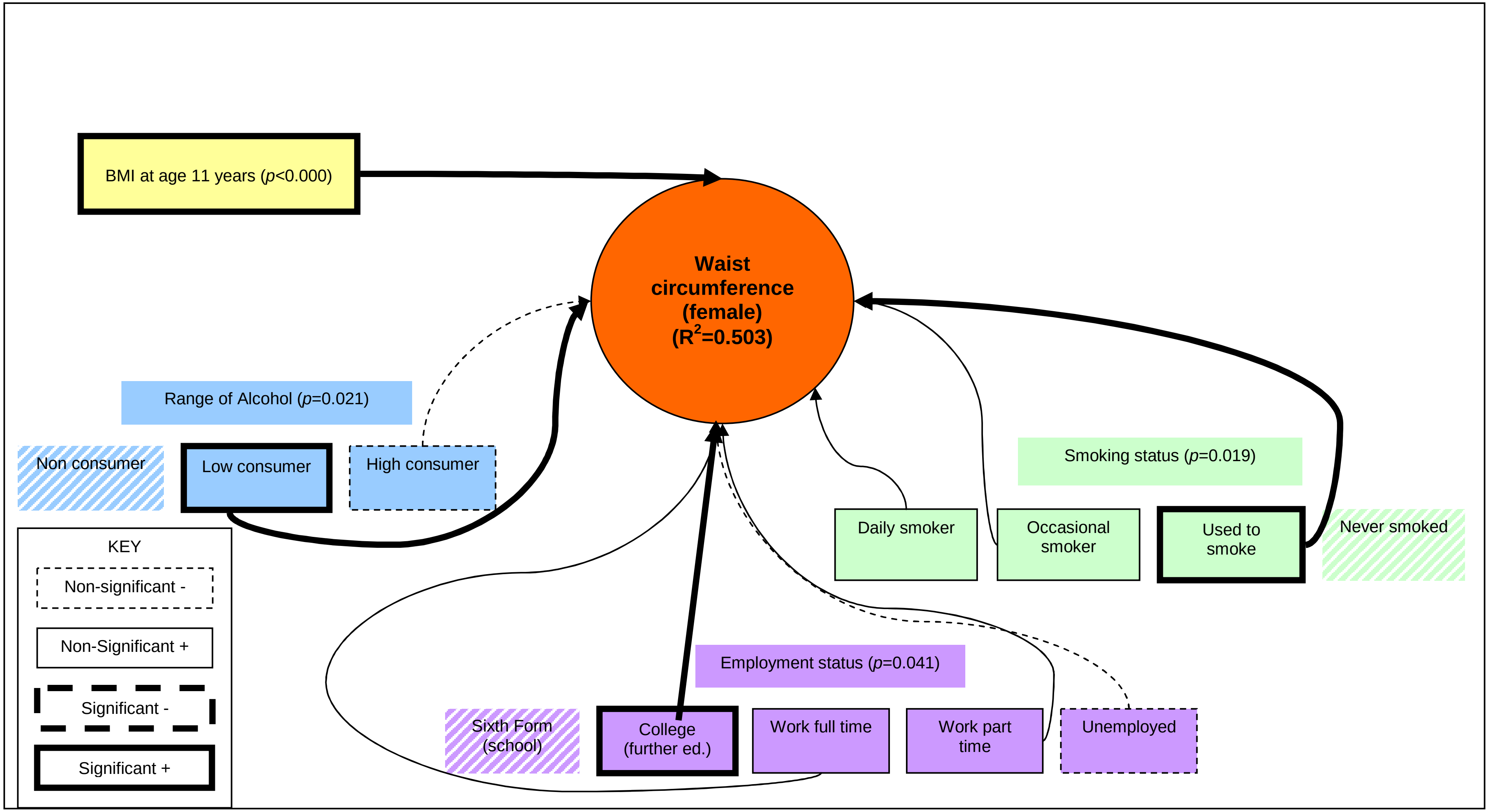

Figure 8.6 Variables found to most strongly predict waist circumference at age 16-18 years (females)

8.6. Variables that most strongly predict waist to hip ratio (WHR) at age 16-18 years

WHR at age 16-18 years (male)
= -0.808
+ 0.209(Log_e BMI at age 11-12 years)

- 0.036 if does not participate in activity
if take part in activity

Equation 8.6 Regression equation to predict waist to hip ratio (WHR) at age 16-18 years (males)

WHR at age 16-18 years (female)
= -0.742
+ 0.151(Log_e BMI at age 11-12 years)

+ 0.011 if high consumption of alcohol
+ 0.039 if low consumption of alcohol
If no alcohol consumed

+ 0.043 if unemployed
+ 0.031 if in part time work
+ 0.037 if in full time work
+ 0.047 if at college
if at 6^{th} form

Equation 8.7 Regression equation to predict waist to hip ratio (WHR) at age 16-18 years (females)

Whilst much less of the variance in WHR at age 16-18 years was explained (Figure 8.7 and Figure 8.8), BMI at age 11-12 years continued to be the strongest predictive factor of WHR of both males and females at age 16-18 years. Intriguingly male WHR at 16-18 years was the only anthropometric outcome predicted by a measure of physical activity. Thus if a male had a high BMI at age 11-12 years they were predicted to have a higher WHR at age 16-18 years, however this effect was reduced if they did not take part in activity (self report) (see Chapter 4.4) at age 16-18 years. These two variables explained 31% of the variance in male WHR at age 16-18 years. Similar to WC (Chapter 8.5), females were more likely to develop a high WHR if they had a high BMI at age 11-12 years, were at college (rather than 6^{th} form) and were low alcohol consumers (rather than consuming no alcohol in the reporting period), however all three variables explained only 22% of the variance in female WHR at age 16-18 years

(Figure 8.8). Although measured ‘hard activity’ was significantly negatively correlated with WHR in both males (R=-0.36) and females (R=-0.28) (Chapter 4) neither of these variables contributed significantly to either model (Figure 8.7 and Figure 8.8).

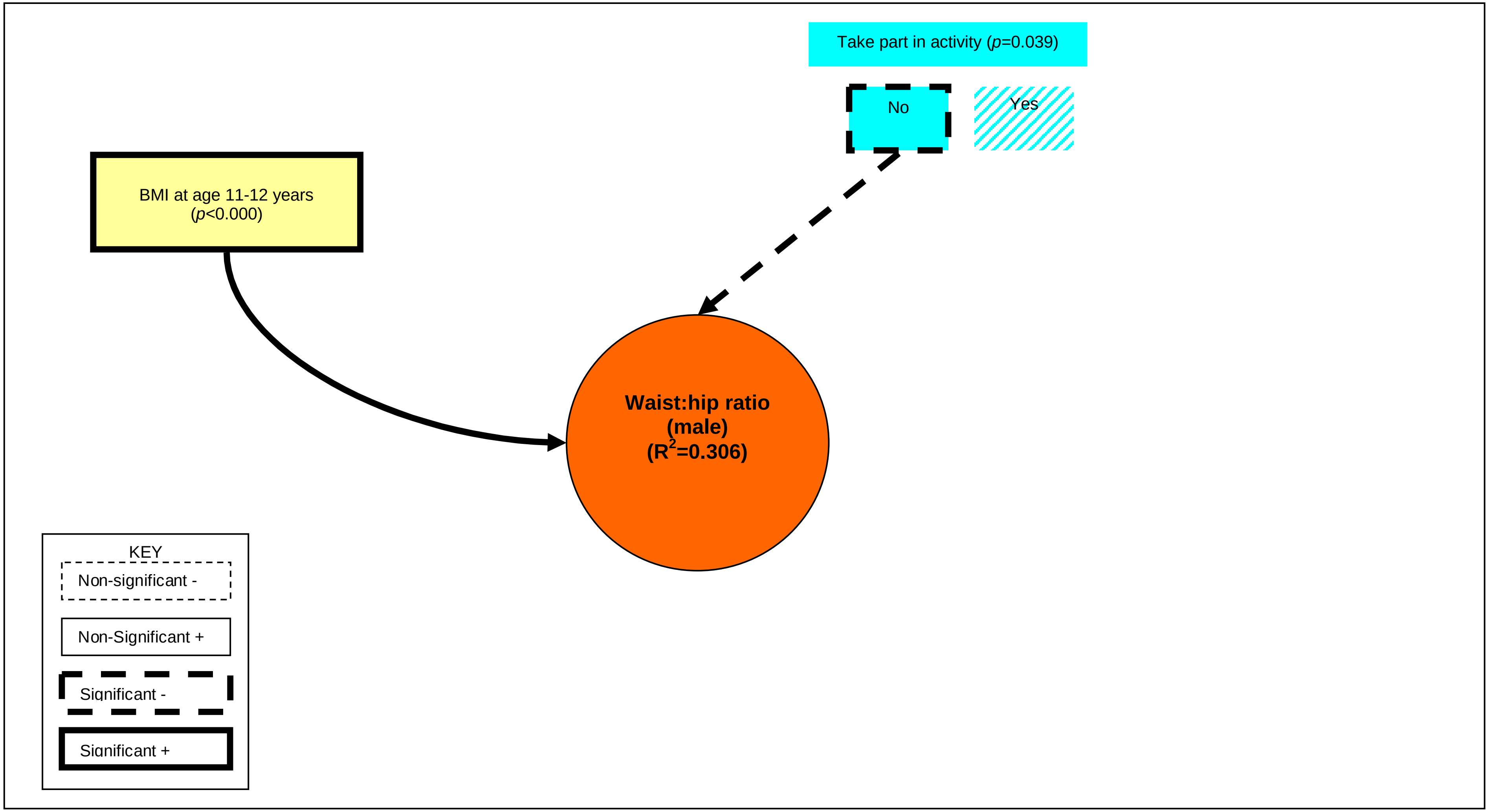

Figure 8.7 Variables found to most strongly predict waist to hip ratio (WHR) at age 16-18 years (males)

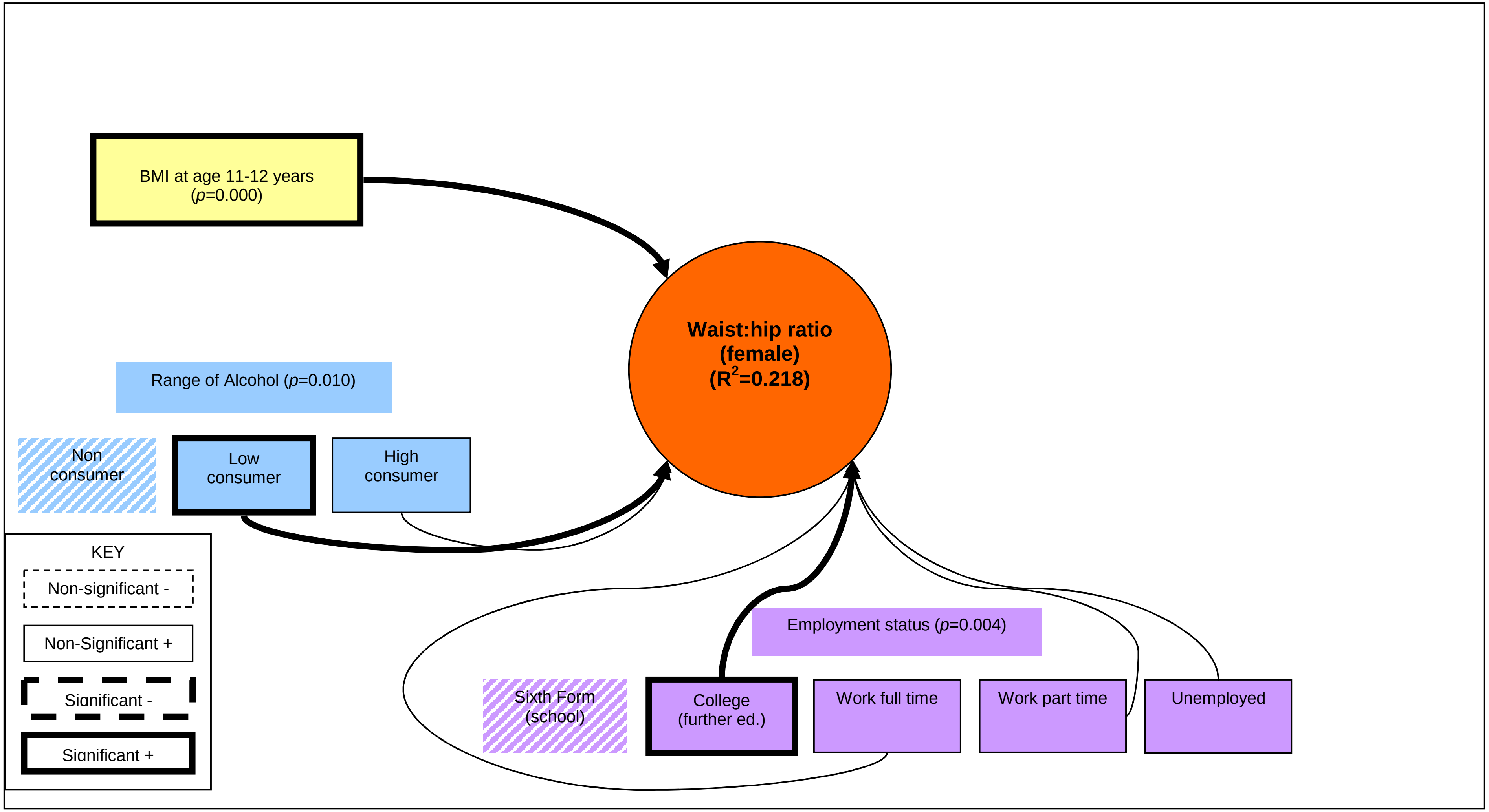

Figure 8.8 Variables found to most strongly predict waist to hip ratio (WHR) at age 16-18 years (females)

8.7. Discussion

The baseline factors tested in the models, based on the findings of a comprehensive review by Parsons *et al*. (1999) of childhood predictors of adult obesity, were adiposity in childhood and diet in childhood (11-12 years) and adolescence (16-18 years). Parsons *et al*. (1999) considered that the relationship between childhood and adult fatness was established, whilst the relationship between childhood diet and adult fatness was less well understood. The remaining factors were based on socio-demographic and lifestyle factors measured at age 16-18 years and a similar study investigating the predictors of adult obesity from age 11-12 years (Craigie *et al.* 2004). In addition, physical activity levels and smoking were included; physical activity due the fundamentals of activity in energy balance and smoking as an indicator of an additional health related behaviours that could have an influence on adiposity through altered patterns of nutrient intake (Dallongeville *et al.* 1998).

Factors found to be predictive of body composition at age 16-18 years differed between the sexes. However it was clear that for both males and females, BMI at age 11-12 years was the strongest predictor of BMI, % body fat, WC and WHR at age 16-18 years. The models illustrate clearly that the influence of BMI in adolescence is strong enough that it is not confounded by any of the other factors that were tested. These findings emphasise the point that having a relatively high BMI in early adolescence is an independent risk factor for having a high BMI and high abdominal fat accumulation in young adulthood and therefore becoming or remaining overweight or obese. Furthermore, from a public health perspective, measures to prevent adiposity in adulthood should be taken during childhood and continued into adolescence.

Current nutrient intake (age 16-18 years) was not found to be a good predictor of body size at age 16-18 years. Although in chapter 4, for females only there were significant negative correlations between total energy intake (MJ/d) and BMI and WC at age 16-18 years (Chapter 4.3) the effect was lost when combined with all other variables in the models. The same finding was true for the significance of association between lower intakes of fat (%EI) and lower % body fat in females (Chapter 4.3). Widely reported difficulties in measuring accurate dietary intake (Chapter 2.4), such as the greater number of females under-reporting their dietary intake (Chapter 5.3) in this study, is the most likely explanation for these findings. However, current dieting behaviour, particularly in females of this age group (Neumark Sztainer *et al.* 2007) may also in part explain these findings. Similarly dietary behaviour at this age of adolescence (age 16-18 years) is unstable (Chapter 7.3.2) and therefore less likely to be predictive of adiposity at this age. At age 11-12 years %EI derived from fat was the only dietary variable found to be predictive of body composition, being a significant predictor of % body fat at age 16-18 years. Suggesting that the effects of high %EI derived from fat on adiposity are already established in childhood, however intervention during adolescence may reduce the effect in young adulthood.

Alcohol intake of both males and females at age 16-18 years was positively and significantly associated with BMI at age 16-18 years (Chapter 4.3) however, there was no predictive effect when combined with other variables in the model. This indicates that the association was not necessarily causative i.e. higher alcohol consumers in late adolescence are not necessarily predisposed to high BMI. Nevertheless the importance of reducing the level of alcohol consumption in adolescence (age 16-18 years) should not be overlooked (Chapter 4.6.5).

Physical activity, either measured directly or self reported was not found to be a good predictor of body composition, the only significant association was a negative effect (relatively small effect compared with the influence of BMI) of not taking part in activity on WHR in males, indicating that males who were physically inactive were more likely to have lower WHR once BMI at age 11-12 years was taken into account. The direction of this association was not surprising given the large body of literature that has produced inconsistent results. Sallis *et al.* (2000), Ball *et al.* (2001) and Ekelund *et* *al.* (2002) for example found greater activity levels to be associated with lower BMI's. Treuth *et al.* 2005 reported BMI positively associated with sedentary time; and negatively correlated with time spent in light activity. Similarly, Ortega *et al.* (2007) reported children and adolescents with low levels of vigorous physical activity were more likely to be overweight. On the one hand the inconsistency of these results could be explained by the way in which the data were analysed, on the other there is a high probability that the findings are as a result of small sample size. Similarly there are a number of validated cut-off points for defining accelerometer counts into activity levels which are likely to produce inconsistent results between studies.

Whilst there were a number of variables found to contribute to the prediction of each measure of body composition the most significant predictor in all outcomes was BMI at age 11-12 years. Evidently the list of variables included is not exhaustive, however due to the timescale and limitations of this thesis only those considered as 'primary variables' have been explored in the production of the models.

It can be speculated that the little evidence predictive of body composition at age 16-18 years might be due to limitations of this study. For example the focus of this thesis is energy balance and its effect on adiposity; the contributors to energy balance are energy intake (dietary intake) and energy expenditure (physical activity). However, body composition is a reflection of long term energy intake and expenditure, and energy intake was measured at two time points whilst energy expenditure was measured at one time point only (Chapter 3). A further limitation of this aspect of the study is that there are only two time points: age 11-12 years and again at a time of much change and transition at age16-18 years. In addition only 6 days of data at each time point were measured, hence a total of 12 days of measurement over approximately six years were recorded. Therefore in order to detect any significant relationship between energy balance and adiposity it may be necessary to increase the frequency of measurement. Similarly, it may be that the methods or duration of assessment were not adequate to truly measure habitual behaviours.

9 FINAL SUMMARY

Overweight and obesity are defined as "abnormal or excessive fat accumulation that presents a risk to health" (World Health Organization, 2005). While genetic make up may be important in determining a person's susceptibility to weight gain, an individual's energy balance is determined by energy intake and energy expenditure. The key causes of the global increase in overweight and obesity are cited as diet and lifestyle factors, such as habitual consumption of energy-dense foods (high in fat, low in fibre and sugar-rich drinks), increased sedentary behaviour and reduced physical activity (Jebb, 2007). Prevention of obesity is a global public health priority and has led to intense research activity seeking to understand the factors which promote or prevent healthy diet and lifestyle behaviours. Exploration of tracking of health-related behaviours and of adiposity can inform policy, and direct interventions to focus on age-groups or life stages which are likely to be most effective in promoting lifelong healthy lifestyle behaviours. Understanding when adult lifestyle behaviours are established is essential to identifying optimum 'windows of opportunity' for intervention.

It is known that being overweight as an adolescent is associated with being overweight as an adult (Lean, 2000; Guo *et al.* 2002; Craigie *et al.* 2004). In addition there is some evidence that eating habits formed in adolescence continue into adulthood (Lake *et al.* 2004a) but few studies have investigated tracking of lifestyle behaviours important in determining obesity risk at this critical stage of the life-course.

The purpose of this study was to test the hypothesis that diet and adiposity track from early to late adolescence. The original aims of this study are presented below with a summary of the main findings relating to each aim:

Aim i) To describe adiposity and lifestyle characteristics (dietary intake, physical activity, smoking behaviour) of these young people at age 16-18 years.

These young people were from various socioeconomic backgrounds, and although distribution were similar to the original study population, there were a greater number of participants from the high (56%) social group than from the middle (25%) and low (12%) social groups (Chapter 4.2).

The mean BMI of all participants at age 16-18 years was 22.3 (22.1 females; 22.4 males) and prevalence of overweight of obesity was 20% in females and 31% in males. Prevalence was lower when classified according to percent body fat (19% females; 12% males). In females there was little effect of social group on BMI and % body fat. There were however social disparities in BMI & % body fat for males, with participants in the high social group exhibiting lower mean BMI and lower mean % body fat than those in the middle and lower social groups (Chapter 4.2 and Chapter 6.2.2). Females were at greatest risk of cardiovascular disease from abdominal fatness (Lean, *et al.* 1995) with 42% of females in the highest quartile for BMI having waist measurements ≥88cm. A further 45% (highest quartile) and 23% (third quartile) were at increased risk (WC≥80cm).

Average total energy intakes (MJ/d) for both males and females were greater than the Department of Health (1991) reference values for 15 to 18 year olds (Chapter 4.2.3). Similarly, almost 50% of both males and females reported consuming almost 50% of their energy from dietary fat. Encouragingly, there were positive associations between EI (MJ/d) and all measures of physical activity in males. In females only there were negative associations with energy intake (MJ/d) and both BMI and WC. There was also a negative association between %EI from fat and % body fat in females but not males.

Of the 49% of participants for whom measured physical activity was recorded (Chapter 4.2.3), 91% of males and 84% of females achieved the health recommendation for engaging in at least[1] moderate activity for more than half an hour per day. Male participants who engaged in hard physical activity (Table 4.13) were more likely to have lower % body fat and lower WHR, but no association was found with BMI.

Cigarette smoking was in the minority, with 20% of all participants reporting smoking either occasionally or on a regular basis. Female smokers were also more likely to be high alcohol consumers. Alcohol consumption during the study period was reported by 68% of participants (60% males; 72% females). Interestingly, high alcohol consumption was associated with high BMI and high % body fat in both males and females.

Aim ii) To identify changes in, and tracking of, adiposity from 11-12 years to 16-18 years.

The prevalence of overweight males (21%) at age 11-12 years increased (+9% points) at age 16-18 years, whilst the percentage of overweight females (27%) decreased (-12% points). The prevalence of obesity in males (6%) at age 11-12 years decreased (-5% points) at age 16-18 years whilst the prevalence of obesity in females (2%) increased (+3% points) by the age of 16-18 years (Chapter 6.1.4).

There were highly significant evidence of tracking of BMI from age 11-12 years to age 16-18 years (Figure 6.2), particularly evident in those in the highest and lowest quartiles for BMI (Chapter 6.2.1); BMI at age 11-12 years was also strongly associated with all measures of adiposity at age 16-18 years (Chapter 6.1.3 and Chapter 8). Females were more likely than males to maintain their BMI classification at age 16-18 years (Chapter 6.2.1). Both males and females of the low social group were more likely than the other social groups, to remain in the highest quartile of BMI (Chapter 6.2.2).

[1] includes moderate, hard and very hard activity

Aim iii)To identify changes in, and tracking of, energy intake and macronutrient contribution to energy of these participants between ages 11-12 years and 16-18 years.

Absolute intakes of food energy (MJ/d) and macronutrients (g/d) of both males and females increased significantly, with greater increases observed in males than females. Overall there was a non significant increase in %FEI from fat over time. In males, a significant decrease in %FEI from carbohydrate was mirrored by a significant increase in %FEI from protein (Chapter 7.1). When intake was expressed per unit body weight, protein intake (g/kg/d) increased in males whilst a decrease was observed in females. Total food energy (MJ/kg/d), fat (g/kg/d) and carbohydrate (g/kg/d) decreased in both males and females.

There were significant Pearson correlations between intakes (MJ/d; g/d; MJ/kg/d; g/kg/d) at age 11-12 years and intakes at age 16-18 years in both males and females, but evidence of tracking (k) was poor (Chapter 7.2). The strongest evidence of tracking was for total food energy intake when expressed relative to body weight (MJ/kg/d) in both males (k=0.33) and females (k=0.24). Evidence of social disparity in intakes of fat (g/d, g/kg/d) for males at age 16 to 18 (aim i) was already apparent at age 11-12 years with males from the low social group consuming highest intakes at both time points.

Aim iv) To determine factors predicting adiposity at age 16-18 years.

BMI at age 11-12 years remained the strongest predictor of BMI and all other measures of adiposity (% body fat; WC; WHR) at age 16-18 years when other factors were added to the models (Chapter 8.3 to 8.6). Other than BMI at age 11-12 years, all other measured factors (Chapter 8.1) were influenced by gender. Smoking status and employment status were significant predictors in each of the models. Physical activity was predictive only of WHR in males only, while alcohol was associated with WC and WHR in females only. Current dietary variables were not found to predictive of adiposity at age 16-18 years when other variables were added to the models (Chapter

8 and Chapter 4). At age 11-12 years %EI derived from fat was the only dietary variable found to be predictive of body composition, being a significant predictor of % body fat at age 16-18 years.

9.1. Description of participants at age 16-18 years

With considerable effort this study achieved complete data from 193 of the 424 (45%) young people who had taken part in a similar study when the subjects were aged 11-12 years. The strengths of this study are that it provides a unique sample of measured dietary intake, anthropometric and physical activity data in young people aged 16-18 years for whom similar data (diet and anthropometric data) are available at 11-12 years. However there is a limitation in that not all the 2000 study sample participated in 2006.

Whilst there was a fairly even gender distribution at baseline (2000), only 34% of males compared with 55% of females participated in this follow-up (2006) study. Although both males and females from the unclassified (Chapter 3.2) social groups were less likely to take part in this follow-up study (only 10% of males and 38% of females from this group participated in this follow up study), the number of subjects in the unclassified group was small and, on the whole, social group appeared to have little effect on participation in the follow-up study. The social group distribution of participants in 2006 was similar to that of the 2000 study with relatively high proportion of participants from the high social group in both studies (58% males, 55% females in 2006; 49% males, 45% females in 2000).

In terms of primary occupation of participants, most participants (83% (73% male; 89% female)) remained in education at age 16-18 years (although it should be noted that some participants also worked part-time whilst studying at college). In terms of primary occupation, males were similar to those of the same age group in the National Diet and Nutrition Survey (NDNS) (Gregory *et al.* 2000) participants. Compared with the NDNS, females in the present study were less likely to have left full time education, which may be a reflection of both secular changes in participation in full-time education and the results of government policy to encourage teenagers to remain in full time education (http://ema.direct.gov.uk).

Adolescence is a period when a significant proportion of females are concerned about their weight (Chapter 2.3.1). For example in a Scottish study of non-obese adolescents (15 years of age) in 2008, 18.8% males compared with 40.1% females in a study of non-obese adolescents were concerned about their weight (Sweeting *et al.* 2008). Given that female non-participants were on average 2.3kg heavier than female participants when aged 11-12 years (Chapter 5), being heavier may have influenced their decision not to take part in this follow-up study. This notion is also supported by the observation that both males and females who were obese at age 11-12 years (n=29) were less likely to take part in this follow-up study (n=22). Subsequently it is highly likely that the proportion of overweight and obese adolescents in this study area of Northumberland is under-represented.

BMI, although widely recognised as an index of adiposity, does not distinguish between fat mass and lean (muscle and bone) mass, or give any information about the distribution of fat in the body and can lead to misclassification in individuals (Chapter 2.2.1). Therefore, at age 16 - 18 years, in addition to BMI, bioimpedance analysis (BIA) was also used to identify overweight or obese prevalence in these study participants. Thus, according to their BMI, prevalence of overweight or obese in this study at age 16 -18 years was 24% (31% males; 20% females), which for males was notably higher than in the NDNS (24%). This could be explained largely by the year on year increase in overweight and obesity, particularly among males (Butland *et al.* 2007). However, when BIA was used as the method of adiposity assessment, the prevalence of overfat /obese was lower (16% (12% males; 19% females)) (Chapter 4). This suggests that 62% of the 21 males classified as overweight or obese according to BMI may be misclassified, and that higher body weights may be attributable to muscular build (in females there was a much higher level of agreement (75%) between the two methods). Alternatively, the cut-offs for overfat/obese used with BIA data may not correspond directly with those used with BMI data i.e. because the two approaches are radically different in what is measured, there is uncertainty about the criteria for making judgments about body fatness which may require further research. Therefore, future epidemiological studies (of all age groups) should also consider other methods of adiposity assessment (such as BIA) as well as BMI in the identification of prevalence of overweight and obesity in populations.

Regardless of potential limitations in BMI in defining those who were 'overfat' almost a fifth of the females and 12% of males were classified as overweight or obese at age 16-18 years. Reports suggest (Guo *et al.* 2002) that there is a greater likelihood of obesity in later adulthood (for example, age 35 years), if individuals end their adolescence with moderately elevated BMI. Therefore on this basis, participants in the present study who are overweight or obese at age 16-18 years may be at greater risk of being an overweight or obese adult than those who were overweight or obese at age 11-12 years (but not at age 16-18 years) (Chapter 6). The health implications of this excess adiposity are numerous: for example, abdominal obesity is a particular risk for type 2 diabetes, hypertension and dyslipidaemia – and is strongly linked to an increased risk of cardiovascular disease (Kopelman, 2007) and of bowel cancer (Larsson & Wolk, 2007). Females are at increased risk if their WC > 80cm (WC ≥94cm males) and the risk is greater with a WC>88cm (>102cm males) (Lean *et al*. 1995). Using these criteria, female participants of this present study at age 16-18 years were already potentially at greater risk of type 2 diabetes, hypertension and CVD from abdominal fatness, i.e. 13 (42%) of the 30 females with the highest BMI also had a WC >88cm (Chapter 4.2.2).

Moreover, given the tracking of BMI between early and late adolescence (Chapter 6) the data reported in this thesis pertaining to adiposity may be an underestimation of the prevalence of obesity in young people in Northumberland because a smaller proportion of the obese children at age 11-12 were followed up at age 16-18 years. Therefore a greater proportion of young people in this area are likely to be at higher risk of developing diseases attributable to adiposity in adulthood than are apparent from this study. Particularly in light of findings from a Scottish study of 15 year olds, where Sweeting *et al.* (2008) reported little evidence of any effect of psychological distress on obesity. Moreover, the authors suggested that there was a failure to recognise obesity and that overweight is accepted as the new 'normal' weight among UK adolescents (Sweeting *et al.* 2008). In the context of public health, age and population appropriate measures to promote well-being and prevent adiposity in adulthood should begin during childhood and be continued into adolescence.

In terms of reported energy intake and contributions made by the macronutrients to energy intake at age 11-12 years these follow-up study participants at age 16-18 years were highly representative of the original study sample for both genders (Chapter 5.1.4). How the intake of energy and macronutrients changed, and tracked from age 11-12 to 16-18 years are discussed later in this chapter. However, at age 16-18 years the average energy intake (EI/MJ/d) of the present study participants (12.5 MJ/d males, 9.4MJ/d females) was higher than the average EAR for adolescents aged 15 to18 years (11.51MJ/d males, 8.83 MJ/d females) (Department of Health,1991) (Chapter 4.6.3). Energy intakes were also higher than those reported in the NDNS (Gregory *et al.* 2000) for both males and females. These findings may be explained in part by the higher prevalence of overweight in the present study, for example energy requirements may be greater as a result of the increased body size, but similarly, prevalence of overweight might be as a consequence of the higher intakes. Also there is a possibility of under-reporting in the dietary data in the NDNS (Rennie *et al.* 2005) and of course that the present study and the NDNS employed different methods of dietary assessment (Chapter 3.8). The NDNS study is the only comparable study of this age group in the UK. There is almost a decade (1997 to 2006) between the data collection periods of the 2 studies and there is a high likelihood that diets of this age group have changed over this period and any comparison made should be considered in this light.

At age 16-18 years the average %EI from fat was lower than that reported in the NDNS (Gregory *et al.* 2000) and below than the recommended level of 35% (Department of Health, 1991) for both males and females. However, more than 47% of both males and females consumed an average of almost 50% EI from fat over the study period (Chapter 4.2.3). The health effects of this excessive intake of total %EI from fat are less understood, however, there are known associations with certain fatty acids and coronary heart disease and cancers. In this study there is little evidence to suggest that high intakes of dietary fat per se were associated with adiposity (Chapter 4.3) which supports the notion that diets high in fat are not the primary cause of excess adiposity in western societies (Willet, 1998, Butland *et al.* 2007). Nevertheless, because high fat diets are likely to be more energy-dense, in the long term if this behaviour continues into adulthood it is highly likely that weight gain will follow, particularly in genetically susceptible individuals (Hill, 2006).

Late adolescence (16-18 years) is a time of increased independence, and in addition to erratic eating behaviour (Chapter 2.3), secular changes such as an increase in alcohol consumption (www.tradingstandards.gov.uk) in young people may contribute to the reported increase in energy intake. Recommended levels for alcohol intake (%EI) are available only for adults >18 years (Department of Health, 1991) and is set at 5% EI. However, a substantial proportion (68%) of these young people, all aged less than 18 years, were already consuming more than the recommended level of 5% of their average daily intake.

The finding that both males and females with high % body fat were more likely to be high alcohol consumers might indicate that high alcohol consumption in adolescence may be a contributory factor, in combination with other lifestyle factors, to the rising obesity epidemic in adulthood (Chapter 8). It could be speculated that consumption of high fat, high salt foods (for example, crisps, peanuts, kebabs and chips) may also be associated with high alcohol consumption, thereby contributing to excess energy intakes and so the higher % body fat reported. However, there were no associations found in this study population either between high intake of dietary fat (%EI), or total energy (EI) and high % body fat which might suggest that alcohol is consumed in place of food by these participants. It is evident that there are clear health implications for excessive alcohol consumption (http://www.dh.gov.uk) and further studies of the association between alcohol and adiposity in adolescence are warranted. Furthermore there is evidence that dietary patterns formed in adolescence (Post *et al.* 2001; Craigie *et al.* 2004) may track into adulthood, but participants would need to be followed-up again in adulthood to establish the true extent of this phenomena.

Data from the self-reported questionnaire (Chapter 4.2.3) revealed that only 55% of males and 23% of females reported taking part in physical activity ('to work up a sweat') on 3 or more days per week. Direct measures of physical activity (accelerometer data) showed that a similar proportion of both males (43%) and females (42%) met the recommendation (Chapter 2.6) for activity in adults (30 minutes per day) and a small proportion took part in at least moderate activity for more than 1 hour per day (16% males; 13% females). This suggests that although these young people did not actively seek to take part in specific activities (Chapter 4.2.3 '*Activity data*'), for some, their lifestyle at this age may be such that it meets health recommendations. It is important to note however, that direct measures of physical activity were available for only 50% of this sample population and therefore these results may not reflect the true picture in the whole sample population. By either self report or direct measures, it is clear that a substantial proportion of this young population are inactive participants

(57% males; 58% females). Such low levels of activity are a particular concern in that this behaviour, if unchanged, will increase the risk of obesity in adulthood.
One of the objectives for measuring activity was to investigate how levels of physical activity might influence, or be influenced, by body size. The most significant findings for the effect of physical activity on adiposity in these young people were the negative associations between hard physical activity and % body fat in males, and between hard physical activity and WHR for both males and females. This suggests that high levels of activity, particularly in these young males offered some 'protection' against high levels of adiposity. Of course such associations cannot address the issue of direction of causality and it is possible that those with higher % body fat (males) or higher WHR (males and females) chose to undertake less hard physical activity.

There was stronger evidence of associations between energy expenditure (in physical activity) and energy intake. For males only, there was a moderate ($r=-0.49$, $p<0.05$) association between high levels of light activity (the more sedentary) and lower reported %EI from alcohol - this was mirrored by higher %EI from fat in males who were less active (fewer than 3 days per week). It could be speculated that sedentary males might be less likely to socialise (Wills, 2005) and perhaps more likely to watch TV or play computer games and to undertake snacking whilst doing so (Utter *et al*. 2003). Conversely, these observations may imply that the males who were more active were also more likely to 'go out drinking', for example after sports activities. This is supported by the striking association that males who engaged in moderate or hard physical activity had higher EI (MJ/d), perhaps to fuel their greater physical activity. There was no significant association between higher physical activity and the contribution made by any other macronutrient to energy intake (%EI) including %EI from alcohol. However, as stated previously, these active males were also more likely to have a lower % body fat, and given that high alcohol consumption per se was associated with higher % body fat, these active males may only represent a small percentage of the high alcohol consumers. Once again the most likely explanation for these findings is the low number of participants in the study and subsequent risk of reporting bias. Therefore further studies of these associations are recommended. The prevalence of smoking was relatively low compared with the national average for smoking among adults in the UK (23% males, 21% females) (www.statistics.gov.uk); and with adolescents who were investigated in the NDNS (Gregory *et al.*2000). In the present study, 15% (13% males, 16% females) of respondents smoked on a daily basis and a further 5% (3% males, 6% females) smoked occasionally. The reasons for smoking or not smoking were not investigated in this study. However smoking prevalence among 16 to 19 year olds has decreased from around 30% in 1998 to around to 20% in 2006 for both males and females (www.ic.nhs.uk). This lower prevalence may be in response to greater health awareness which reflects the secular reduction in smoking prevalence in the UK (www.statistics.gov.uk; www.ic.nhs.uk).

Female smokers were significantly (p=0.01) more likely to be high alcohol (%EI) consumers than those who had never smoked. Although there were only a small number of participants who were classified as smokers, the significance of this relationship between smoking and alcohol consumption would indicate a cluster of these unhealthy behaviours in these 16-18 year old females, particularly in those also exhibiting a high % body fat. There was no association found between either alcohol intake or smoking and any of the measures of dietary intake. Further studies of this age group would need to identify whether this is behaviour representative of this study population alone or of the national population.

9.2. Changes in anthropometry, especially in adiposity, between ages 11-12 and 16-18 years

Longitudinal studies of obesity among adolescents (for example, Sweeting *et al.* 2008) have shown steeper increases in BMI of males compared to females over time. In this study there was little gender difference in BMI of these participants in childhood (age 11-12 years) or adolescence (age 16-18 years). Whilst on average males were significantly (p<0.001) taller and heavier than females (at age 16-18 years), there were similar increases in BMI for both genders (males +2.8 units and females +2.9 units). This narrow gender difference in BMI at age 16-18 years is largely explained by the complication that during adolescence not only height and weight, but also body composition is still changing (Friedman, 1997; Page and Fox, 1998).

9.2.1. Tracking of adiposity in these young people

The most striking observation from this study is that whilst a large proportion of overweight 11-12 year old participants had moved from overweight (36% of overweight males and 50% of overweight females) or obese (25% males only) to normal weight, the majority of participants had maintained their BMI classification status over the 6 years of study. It should also be considered that some children (11-12 year olds) of the present study participants may have had relatively high weights primarily due to high lean mass, rather than high body fat levels which are not identified by BMI alone (Chapter 2.2). Nevertheless, significant positive relationships were identified between BMI at age 11-12 years and all measures of adiposity (BMI, % body fat, WC) at age 16-18 years for both males and females. This not only supports the hypothesis that adiposity tracks from 11-12 years to 16-18 years, it also provides strong evidence that BMI at age 11-12 years is indicative of % body fat and WC at age 16-18 years. These findings emphasise that being overweight or obese at age 11-12 years increases greatly risk of being overweight or obese at age 16-18 years. However, as stated, this progression is not inevitable. While a substantial proportion of overweight or obese children at age 11-12 years became normal weight at age 16-18 years, a small proportion of normal weight participants in the present study became overweight or obese at age 16-18 years. Therefore lower weight in childhood should not be a cause for complacency since it offers no certain protection against adult obesity and associated risk adult disease (Wright *et al.* 2001).

During adolescence, many young people are concerned with body image (Tiggeman, 2005; Sweeting *et al.* 2008) and body weight issues and some are reported to engage in dieting behaviours to control their weight (Neumark-Sztainer *et al.* 2002; Butland *et al.* 2007) (Chapter 2.3.1) which in part might explain the reduction in weight status, particularly of females. However Neumark-Sztainer *et al.* (2006) found that dieting and weight control behaviours, particularly unhealthful behaviours (e.g. meal skipping and smoking) at age 12 years were associated with weight gain (rather than weight loss) at age 17 years. Furthermore the author reported ‘dieting’ at age 12 years was associated with higher BMI values and a greater prevalence of overweight status in both males and females (Chapter 2.3.1). This would indicate a potential opportunity for increased education to improve knowledge in adolescence (age 11-18 years) on the importance of healthful behaviour, but also to facilitate a positive change and to identify and provide support for those young people ‘at risk’ of adult disease.

Longitudinal studies with measurement at frequent time intervals have reported stronger tracking over time than those with longer time intervals between measurements. Wardle *et al.* (2006) for example reported that adiposity tracked strongly over time and BMI correlations were greater than 0.9 at one and two year intervals and above 0.8 for three and four year intervals. In agreement with these previous findings, tracking of BMI was stronger in the present study (across a 6 year time interval) (R=0.65 males, R=0.75 females) than in a longitudinal study of Northumberland adolescents (age 12 years) into adulthood (age 33 years) (across a 20 year time interval) (R=0.58 males, R=0.56 females) (Craigie *et al*. 2004). These findings suggest that longitudinal studies carried out over longer periods of time with shorter intervals may provide better evidence for the extent of tracking of adiposity (Wardle *et al.* 2006; Johannsson, 2006).

The prevalence of obesity is reportedly greater in lower social groups (for example HSE, 2004; in Butland *et al.* 2007; Wardle *et al.* 2006) however few studies have reported the effect of social group on tracking of adiposity. Whilst at age 11-12 years there was evidence of an effect of social group on BMI for males in the present study, the mean BMI of females was greater in the high and middle social groups. However, at age 16-18 years mean BMI was greater in the low social group for both males and females (though significantly so only for males), suggesting that social disparities in adiposity emerge later in childhood and in females may not become apparent until adulthood. It is important to note that in the present study when the sample is divided by social group, the number of respondents in each BMI category within each social group become much smaller so the power to detect any social class effects is reduced substantially.

9.3. Changes in the energy intake of these young people between age 11-12 and 16-18 years

Whilst food energy intake was greater in males than in females at both age 11-12 and 16-18 years, the difference between the sexes increased over time (0.68MJ/d at age 11-12 years *v.* 2.83MJ/d at age 16-18 years). This difference can be explained by the difference in body size between males and females which increase as these young people approach physiological maturity (Chapter 2.2.1). Males were on average (12kg) heavier and (15cm) taller than females at age 16-18 years (Chapter 4.4.2) and when scaled for body weight (i.e. energy intake data expressed as MJ/kg/d) there was no significant difference in food energy intake between males and females. As discussed previously (Chapter 9.1) the increases in food energy intake between age 11-12 and 16-18 years may be due to secular changes, but they may also be reflective of increased energy demands at this age (Chapter 2). However, whilst some of these participants might have active lifestyles reflective of their food energy intake at this age (Chapter 4), a decrease in energy expenditure (Butland *et al.* 2007) in young adulthood might not be mirrored by a decrease in energy intake (Craigie, *et al.* 2004), thus resulting in weight gain, a notion which might be investigated further in a follow-up study of these young people in adulthood such as that of Craigie *et al* 2004 for example.

For both males and females there was little change in the average %FEI from fat (0.12%) which was around the recommended level of 35% at both ages (Department of Health 1991). However this small change in fat intake (%FEI) and a similar decrease in carbohydrate (%FEI), was mirrored by an increase in percent energy from protein (%FEI)(Table 7.3). Preoccupation with body weight and diet is common, especially in female adolescents (Barker *et al.* 2000) and the advent of 'protein diets' such as the Atkins diet (Atkins, 2003) may have influenced the intake of these participants, particularly females. In a UK study of adolescent females, Barker *et al.* (2000) found that girls who reported being less satisfied with weight were also more likely to report lower intakes of percentage energy from fat and higher percentage energy from protein (Chapter 2.3.1). This preoccupation with body image also occurs in males for example consuming certain foods such as protein drinks as an aid to make them more muscular, or to gain or lose weight (Neumark-Sztainer *et al.* 1999). In addition to fat, carbohydrate and protein, at age 16-18 years alcohol contributed to the energy intake of more than 68% of these study participants (Chapter 4.2.3). When alcohol was taken into consideration, the direction of change (between the surveys in 2000 and 2006) as %EI for all macronutrients is the same as for %FEI. For example, intakes of %EI from fat and carbohydrate also decreased in both males and females at age 16-18 years while protein intake in both males and females increased, albeit to a slightly lesser extent, when alcohol was included. Therefore this reduction in energy intake from fat (%EI) and carbohydrate (%EI) is not simply a reflection of increased protein intake, but also of the addition of alcohol to the diet of these study participants. The effects of alcohol consumption have been discussed previously (Chapter 9.1)

9.3.1. Tracking of energy and macronutrient intake from age 11-12 to 16-18 years

As reported by other authors (Cusatis *et al.* 2001; Robson *et al.* 2000; Gallagher *et al.* 2005; Post *et al.* 2001), overall tracking of food energy and macronutrient intakes in the present study was weak but statistically significant. This contrasts with the much stronger tracking observed for body weight (Chapter 6). However in agreement with Dunn *et al.* (2000) and Craigie *et al.* (2004) when participants were grouped into quartiles by their intakes there was a tendency to remain within the broad category of ranking with over 50% of those who were very low (MJ/d) or very high (MJ/d) consumers at age 11-12 years remaining as such at age 16-18 years.

Of particular note is the small percentage of females who maintained their position in the lowest quartile (26%) for fat intake (%FEI). Almost three quarters of this quartile increased their percentage energy from fat, which may be consistent with the notion that many adolescents (age 16-18 years) eat an unhealthy, and in particular a high fat, diet (Henderson *et al.* 2002; Larson *et al.* 2006). These findings were similar to those reported by Cusatis *et al.* (2000) in which females with the highest diet quality at age 12 years showed significant deterioration throughout adolescence.

It is widely acknowledged that measurement of dietary intake is subject to methodological errors such as mis-reporting (Chapter 5.3). This may help explain the weaker tracking of nutrients compared with body size (height and weight) which can be measured with greater accuracy and precision (Chapter 2.2.1). In addition, changes that occur during adolescence (age 11-18 years) are erratic (Wills, 2005) and it might be intuitively assumed that in striving for greater autonomy, intakes at this age would be less likely to show evidence of tracking than in childhood for example. In childhood, not only are dietary intakes subject to parental guidance but also reporting of dietary intakes may also be influenced by parents therefore increasing the probability of tracking at this younger age range (age 4-10 years) (Singer *et al.*1995). During adolescence, (non-familial) societal influences become more important and therefore change is more likely to occur over this time (Chapter 2.3.1). It is also possible that, as with BMI (Chapter 6), dietary behaviour in late adolescence may be more inclined to stabilise and persist into adulthood. However no studies to date have explored this notion which could be investigated further in a follow-up study of these participants. Furthermore it might be postulated, that if dietary intake does stabilise in late adolescence, this would be a key time for preventative measures to address unhealthy behaviours to be instigated.

Interestingly none of the studies discussed in this thesis reported any social group effects on the tracking of energy intake. In the present study, the only evidence of social disparity in tracking was in dietary intake of fat for male participants. In absolute terms (g/d), there was an increase in fat intake across all social groups but there was a significantly greater increase in participants from the low social group. This social disparity in fat intake continued to be evident when body weight (g/kg/d) was taken into consideration suggesting that the greater fat intake was not simply a reflection of greater increase in body mass. This disparity may in part be explained by the environments (Lake and Townshend*.* 2006) in which participants live and work. For example, in lower socioeconomic areas there may be a greater number of food outlets where the availability of healthy choices are constrained, such as ‘pie shops’ and ‘fish and chip shops’. Education (or lack of) may also be a factor in the choices of these young males for whom health and nutrition is not a priority (Chapter 2.3).

9.4. Predictors of adiposity at age 16-18 years

Diet and lifestyle factors, namely increased consumption of energy-dense foods (high in fat and low in fibre) and sugar-rich drinks, increased sedentary behaviour and reduced physical activity are cited as the primary cause for the high rates of excessive body fat (Jebb, 2007). However, as discussed previously there was little evidence of such associations in the present study (Chapter 4).

The factors which were found to be predictive of body composition at age 16-18 years differed between the sexes. However it was clear that for both males and females, BMI at age 11-12 years was the strongest predictor of BMI, % body fat, WC and WHR at age 16-18 years. The models in Chapter 8 illustrate clearly that the influence of BMI in adolescence is strong enough that it is not confounded by any of the other factors that were tested. The mechanism(s) responsible for this stability of BMI is not known and could reflect tracking of adiposity-related behaviours underpinned by genetic determinants of these behaviours and of body size/ body composition per se. Nevertheless these findings emphasise the point that having a relatively high BMI in early adolescence is an independent risk factor for having a high BMI and high abdominal fat accumulation in young adulthood and therefore becoming or remaining overweight or obese.

Current energy and/or nutrient intake (at age 16-18 years) was not found to be a good predictor of body size at age 16-18 years. Although, as reported in Chapter 4, for females only there were significant negative correlations between total energy intake (MJ/d) and BMI and WC at age 16-18 years (Chapter 4.3), the effect was lost when combined with all other variables in the models. The same finding was true for the significance of the association between lower intakes of fat (%EI) and lower % body fat in females (Chapter 4.3). Higher intakes of dietary fat (g/day) were significantly associated with lower BMI and % body fat (both R=-0.22, p<0.05) at age 16-18 years. These findings may be explained by the greater number of females likely to be under-reporting their dietary intake (Chapter 5.3). However they may also reflect current dieting behaviour, particularly common in females of this age group (Neumark Sztainer *et al.* 2007). For example, Barker *et al.* (2000) reported that girls aged 14-16 years with a BMI of 24kg/m^2 were 19 times more likely to diet than those with a BMI of less than 19kg/m^2 (Chapter 2).

In combination with BMI at age 11-12 years and smoking status at age 16-18 years, %EI derived from fat at age 11-12 years was the only dietary variable found to be predictive of body composition in females, being a significant predictor of % body fat at age 16-18 years. These observations suggest that the effects of a high %EI derived from fat on adiposity are already established in childhood and offer an opportunity for intervention during adolescence that may reduce the risk of higher adiposity being maintained into young adulthood.

Alcohol intake of both males and females at age 16-18 years was positively and significantly associated with BMI at age 16-18 years (Chapter 4.3) but this factor was not predictive when combined with other factors in the model. This indicates that the association was not necessarily causative i.e. higher alcohol consumers in late adolescence are not necessarily predisposed to high BMI. Nevertheless, for other health and social reasons, the importance of reducing the level of alcohol consumption in adolescence (age 16-18 years) should not be overlooked (Chapter 4.6.5).

In Chapter 4 it was reported that higher levels of hard physical activity were associated with lower % body fat in males and with WHR for both males and females. However, in the regression models, physical activity, either measured directly or self reported, was not found to be a good predictor of body composition at age 16-18 years. The only significant association was a negative effect (relatively small effect compared with the influence of BMI) of not taking part in physical activity on WHR in males, indicating that males who were physically inactive were more likely to have lower WHR once BMI at age 11-12 years was taken into account. The direction of this association was not surprising given that the large body of literature that has reported inconsistent findings. Sallis *et al.* (2000), Ball *et al.* (2001) and Ekelund *et al.* (2002) for example found greater activity levels to be associated with lower BMI's. Treuth *et al.* (2005) reported BMI positively associated with sedentary time; and negatively correlated with time spent in light activity but only in females. No association was found for males. Similarly, Ortega *et al.* (2007) reported that children and adolescents with low levels of vigorous physical activity were more likely to be overweight. In contrast, others (Trost *et al.* 2001) reported no association between physical activity/ sedentary behaviour and adiposity. On the one hand the inconsistency of these results could be explained by the way in which the data were analysed (for example using categorical variables as oppose to continuous data), on the other there is a high probability that the inconsistent findings are as a result of small sample sizes. Similarly there are a number of different cut-off points for defining accelerometer counts into the various activity levels which are likely to produce inconsistent results between studies. More high powered prospective studies are required to evaluate this relationship between physical activity levels and adiposity, particularly in adolescents.

Smoking status and employment status were also highlighted as predictors of adiposity in many of the models (Chapter 8). However, whilst there is a strong possibility that these factors might contribute to adiposity in the general population, the relationship is not fully understood. Furthermore, in this study the findings are complicated by the fact that both of these factors were distinctly biased (i.e. 66% were non-smokers; and 83% were in full time education). Further work on the predictors of adiposity would be valuable in the advancing understanding the aetiology of obesity which is clearly a global challenge. The methods challenges and results of this study could be used to inform such further work.

As reported in other studies of adolescents, there was little effect of social group in the prediction of adiposity in late adolescence. These findings support the notion that young people's lives may be less constrained by traditional structures such as gender and class (Wills, 2005; Sweeting *et al.* 2008) and whatever lifestyle choices that might contribute to body size in young adulthood does not appear to be influenced by social group. However as with employment and smoking status, the social groups were not equally represented in this follow-up study cohort, which constrains the ability to draw definitive conclusions about the impact of social group (Chapter 4) and a more socially representative data set might produce somewhat different results.

9.5. Limitations of the study

While there is no doubt that failure to recruit 100% of the original sample (Chapter 4.1) places some limitations on the results of this work, recruitment of these young people in itself proved to be challenging (Chapter 4). This was due in part to the limited information collected during the original study in 2000. When the study was carried out in 2000, there was no expectation of a follow-up study of these study participants and because the field-work for that study was carried out in schools only (Fletcher, 2003), full addresses and telephone numbers of participants were not collected and recorded. As a consequence, in the present follow-up study the primary means of contacting these young people was through the primary schools which they had left several years previously. However, obtaining personal information or destination school information retrospectively proved to be a challenge because of the constraints imposed by data protection laws.

While the method of recording food intake data remained relatively unchanged between the 2000 and the 2006 studies, the method of portion size estimation was changed. In 2000, food models were used to facilitate comparisons with previous studies of children of the same age in the same schools in 1980 and 1990 (Hackett, *et al.* 1982; Adamson *et al.* 1992). In adults there is good evidence to support the use of photographs to estimate portion size and nutrient intake (Nelson *et al.* 1994; Robinson *et al.* 1997; Gerber *et al.* 1997) but evidence of the utility of food photographs in late adolescence was scarce at the time of data collection (2000). However, there have been major advances in this area in recent years and age-specific food atlases have been produced (Foster *et al.* 2006) with the oldest age range being 11 to 16 years. For the present study (of respondents aged 16-18 years) it was deemed appropriate to use Nelson *et al.* (1997) food atlas for use in adults. However, this may have produced a bias in the estimation of portion sizes since it is not known which of the atlases produced by Foster *et al.* (2006) and those of Nelson *et al.* (1997) is most appropriate for the “in between” age group (16-18 year olds) investigated in the present study.

For most respondents in the present study at age 16-18 years, the interview was carried out in the school which they were attending. However those study participants who had left school or were on study leave were interviewed at their home (Chapter 3). In a small number of cases where a parent of the participant was at home at the time of interview, the participant was prompted and inadvertently assisted in the recall of dietary information by the parent. Whilst this potentially increases the accuracy of the information it does introduce a possible reporting bias in respect of other participant data and of the data at age 11-12 years (which was collected in school in the absence of parents).

An additional limitations of the study, is the lack of data on physical activity at age 11-12 years. However, to my knowledge, currently there are no other physical activity data of this nature in this age group (age 16-18 years) in the UK and, at the very least, the present study provides a basis for future research in this area.

As with dietary intake, physical activity is notoriously difficult to measure accurately in free-living populations. However the application of accelerometers in such research has expanded exponentially over the last decade and facilitated greatly direct measurement of physical activity (Troiano, 2006). There are however, limitations to the use of accelerometers (Chapter 2.6). In addition to those described in Chapter 2.6, participants in this study also reported removing the monitors for contact sports such as rugby and football and for activities such as gymnastics and 'clubbing' (Chapter 4.6.4). The failure to accurately measure these activities will lead to underestimation of the physical activity of individuals who regularly participate in such activities (Cooper, *et al.* 2000).

Accelerometer data can be used to assess moderate to vigorous activity as well as physical inactivity, but in general however, validation studies have been carried out under controlled laboratory conditions rather than with free-living individuals (Trost *et al.*1998, Freedson *et al.* 1998; Cooper *et al.* 2000). Furthermore whilst accelerometers provide an estimate of activity volume, estimation of energy expenditure from such measurements requires further assumptions and calculations and presents addition challenges in validation studies (Corder *et al.* 2007).

Despite these limitations, accelerometry provides a promising means of physical activity measurement, particularly in those whose primary mode of activity is walking. Once limitations such as the inability of accelerometers to capture some activities commonly reported by these young people (Chapter 4.2.3 *'Actigraph accelereometer data*) have been overcome, use of accelerometers in combination with heart rate monitoring (Rennie *et al*. 2006) will be a very valuable approach for the assessment of physical activity patterns in young people.

It can be speculated that limitations in the tools available for estimating the key determinants of energy balance viz. energy intake and energy expenditure may have contributed to limited evidence obtained in this study on factors predictive of body composition at age 16-18 years. For example the focus of this thesis is energy balance and its effect on adiposity; the contributors to energy balance are energy intake (dietary intake) and energy expenditure (physical activity). However, body composition is a reflection of long term energy intake and expenditure, and energy intake was measured at two time points whilst energy expenditure was measured at one time point only (Chapter 3). A further limitation of this aspect of the study is that measurements were made at only two time points viz. at age 11-12 years and again at age16-18 years - a time of much change and transition. In addition only 6 days of data at each time point were measured, hence a total of 12 days of measurement over approximately six years were recorded. Therefore in order to detect any significant relationship between energy balance and adiposity it may be necessary to increase the frequency of measurement. Similarly, it may be that the methods or duration of assessment were not adequate to truly measure habitual behaviours.

9.6. Further work

Evidently, studies of this age group (16-18 years) are scarce and given that it is a period of rapid growth both physically and emotionally, further research is essential to form an understanding of the factors that influence the behaviour of this age group.

In contrast to findings for the tracking of diet, this study provides strong evidence that BMI tracks from early to late adolescence and that 11-12 year olds who were overweight or obese were at greatest risk of being overweight or obese at age 16-18 years. However, during this important period of physiological change opportunities exist to become a healthy weight even if the individual is overweight as a child. Evidence from other studies (Guo *et al*. 2002) suggest that individuals entering young adulthood overweight are likely to remain overweight or become obese throughout adulthood, therefore the importance of reducing the prevalence of obesity in childhood should not be overlooked. While BMI has been found to track well the limitations of BMI as a measure of adiposity of the individual are well recognised i.e. some children may have relatively high BMI primarily because of high lean mass, rather than high body fat content. For this reason, future studies should consider measurement of waist circumference and of % body fat (e.g. by bioelectrical impedance) in addition to BMI for a more accurate estimation of overweight and obesity in children and adolescents. Research into the levels of alcohol consumption and the reasons for excessive drinking in this age group could provide valuable background information to enable successful intervention; there is limited and conflicting information available on the link between alcohol and obesity. Well-designed studies of both adults and young people are required to fully understand the effects of excessive alcohol consumption on overweight and obesity in young people; findings from this study indicate there was a significant positive correlation between high alcohol intakes and BMI and % body fat in both sexes, and with WC in males.

Although valuable data were obtained on physical activity levels in these participants, it is important to note that these data represent only 50% of this sample population and therefore percentages may be higher or lower in the whole sample population. Therefore further research into physical activity and sedentary behaviour in this age group, and work to identify how best to maintain or re engage physical activity in adolescents of this age (16-18 years) is warranted. Particular attention should be given to the high level of inactivity (57% males; 58% females) in these participants, which, if maintained into adulthood, may increase the risk of obesity.

A further area for future study is the notion that decreases in energy expenditure (Butland *et al.* 2007) of adolescents as they mature into adulthood may not be mirrored by decreases in energy intake. Such positive energy balances are likely to result in weight gain and, eventually, to greater prevalence of overweight and obesity, particularly in adult males (Van Lenthe, *et al.*1996; Craigie, *et al.* 2004).

9.6.1. Health implications and initiatives

It is evident that in this small sample of adolescents that there are important health issues to be addressed; it is likely that these issues are applicable at least to some extent to the UK adolescent population as a whole. For example excessive alcohol intake, erratic eating patterns and sedentary lifestyles all have long term health implications. In this present study a number of plausible factors were identified that may contribute to the increasing prevalence of obesity, for example, energy and macronutrient intake, and lifestyle choices such as smoking, alcohol consumption and physical activity. However, as identified in the UK government report ''Foresight: Tackling Obesities: Future Choices' (Butland *et al.* 2007) there is no simplistic explanation for the causes of overweight and obesity.

This present study does however provide clear evidence that adiposity tracks from childhood to adolescence therefore it is imperative that prevention programmes in this age group are considered high priority. Research has identified that weight gain in most individuals is rapid, but once gained it is difficult to lose (Butland *et al.* 2007). The mechanism responsible for this stability of BMI is not known, but it could reflect a tracking of 'build', a genetic propensity for adiposity, a persistence of behaviours that influence energy intake and/or expenditure, or that in some way factors present in childhood or early adolescence lead to permanent metabolic changes that persist into adulthood. Whatever the reason, a high BMI in adulthood is a known risk factor for a number of health consequences (e.g. diabetes, cardiovascular disease and cancer). Therefore preventing overweight and obesity in childhood and/or adolescence could be an effective method to prevent further increases in obesity and the associated health problems, and personal and societal costs in adulthood.

As outlined in Chapter 2.3 the UK government report ''Foresight: Tackling Obesities: Future Choices' when addressing the causation, prevention and treatment of overweight and obesity there are numerous factors to consider and subsequently no simple solution. Addressing only one aspect of the problem will not provide sustainable changes.

Perhaps we need to lose the stigma of the term ‘healthy eating’ which might be a barrier to change. For example if children and adolescents have what is perceived as a ‘healthy’ lunch box they might be teased that they are ‘not cool’ or ‘unfashionable’ or labelled as ‘geeks’. Recent evidence from work emerging from the Dept of Health Public Health Research Consortium supports this negative image of healthful behaviours (particularly food behaviours) in young adolescents (http://www.york.ac.uk/phrc/PHRC%20B2-06%20Exec%20Summary_FV.pdf). We do not label exercise as ‘healthy’ (because it is all beneficial to health) but there are different levels and activities that are better suited to one person than another. In the same way all (or at least most) ‘food’ is good for you, as it provides energy to sustain life, but too much of one thing or too little of another may affect individuals and populations differently. In terms of food intake and nutrition the approach may be to educate on the benefits of a balanced diet – and not excluding any foods but teaching about the importance of moderation. There is an urgent need, most particularly for clear messages to be given by the media working in partnership with government agencies and health professionals that a balanced diet is the way forward and not including this food and excluding that food – there are so many mixed messages that lead to confusion in the population. A fundamental change in people’s attitudes about the choices they make is required.

Overweight and obesity, moreover, poor health is not unique to one age group. The causes at an individual level are many and varied and differ between population groups and across a person’s life course. Subsequently there is a clear need for initiatives to provide support and intervention at every level.

In the community many youths and adults may have left education without the skills and knowledge to adopt a ‘healthy’ lifestyle. Community workshops and youth initiatives have the opportunity to provide young people and parents with the facilities and training to obtain these skills and knowledge to adopt healthy lifestyle choices.

Discussion groups and opportunities to engage with others in a neutral setting will provide young people with better social opportunities and empower them with the skills to make positive decisions. Building healthy communities, such as community projects to build allotments would allow young people to engage in the production of the food they eat and also reap the rewards of their labour.

Schools, through the curriculum and the wider school environment and ethos, from primary age continuing through to young adulthood have the opportunity to provide education from the fundamentals of nutrition and its importance throughout the life course. This approach has the advantage of not stigmatising those that are overweight or obese, but identifying that everyone is at risk of health problems later in life from poor nutrition throughout their life course. The environments that the schools provide both inside and outside the school setting such as facilities for engaging in physically challenging activities, after school clubs, dining facilities are an important aspect of obesity prevention. Food technology classes that teach how to cook practical wholesome dishes such as rice, pasta and vegetable dishes, (as oppose to puddings and desserts) can provide not only the skills to cook, but to form the practical basis of nutrition education which is reflected in the school food policy now in place (http://www.schoolfoodtrust.org.uk).

There is opportunity to work with food retailers, reducing the cost of foods perceived as health foods such as fresh fruit and vegetables, unprocessed meat and fish products and nuts, may encourage consumers, particularly from low income families, to make better choices for health. There is a pilot scheme operating under the auspices of Change4Life (http://www.nhs.uk/Change4Life/) which is a partnership between the Dept of health and convenience stores in low income areas increasing the availability of high quality, reasonably priced fresh fruit and vegetables. Larger retailers offer '5 a day promotions' with reduced cost of at least 5 different fruit and vegetables each day. A further step would be to reduce the availability of other foods that are commonly perceived as ‘value for money,’ but perhaps not particularly healthful for a balanced diet; this may discourage consumers from buying these foods in excess. One such example might be to discard the promotion of offers such as ‘buy one get one free’ and ‘three for two offers’ on multipacks of crisps, fizzy drinks, sweets and high sugar cereals.

Change4Life is a multi faceted social marketing programme which has focussed initially on families with young children and has recently turned its attention to adults. This is partnership between Government departments, industry, retailers and includes marketers with skills in ‘selling a product’. As yet, there has been no particular focus on adolescents and young adults; it is likely the approaches to date will have had little impact on young adults (with the possible exception of increased availability of fresh produce in corner stores frequented by young people). An opportunity exists to use the skills of the Change4Life campaign perhaps working with the School Food Trust and organisations like Connexions to develop social marketing and interventions which would engage young people and make ‘being healthy’ ‘cool’.

(Hackett *et al.*, 1983; Caspersen *et al.*, 1985; Schofield *et al.*, 1985b; Schofield *et al.*, 1985a; Davis & Furnham, 1986; Holland *et al.*, 1988; Department of Health, 1989; Holland *et al.*, 1989; Livingstone *et al.*, 1990; Altman, 1991; Frank, 1991; Holland *et al.*, 1991; Stein *et al.*, 1991; Adamson *et al.*, 1992; Holland *et al.*, 1992a; Holland *et al.*, 1992b; Livingstone *et al.*, 1992; Holland *et al.*, 1993; Serdula *et al.*, 1993; Kelder *et al.*, 1994; Bingham *et al.*, 1995; Boulton *et al.*, 1995; Chan *et al.*, 1995; Singer *et al.*, 1995; Chan, 1996; Jain *et al.*, 1996; Lean *et al.*, 1996; Mahoney *et al.*, 1996; Shepherd & Dennison, 1996; Torun *et al.*, 1996; Van Lenthe *et al.*, 1996; Han *et al.*, 1997; Lake *et al.*, 1997; Power *et al.*, 1997; Whitaker *et al.*, 1997; Berenson *et al.*, 1998b; Feunekes *et al.*, 1998; Johansson *et al.*, 1998; Sichert-Hellert *et al.*, 1998; Freedman *et al.*, 1999; Guo & Chumlea, 1999; Neumark-Sztainer *et al.*, 1999; Oliver & Wardle, 1999; Society for Adolescent Medicine, 1999; Barker *et al.*, 2000; Cavadini *et al.*, 2000; Cole *et al.*, 2000; Cooper *et al.*, 2000; Dunn *et al.*, 2000; Gregory *et al.*, 2000; Lytle, 2000; Martinez, 2000; Nelson, 2000a; Robson *et al.*, 2000; Samuelson, 2000; Taylor *et al.*, 2000; Trost *et al.*, 2000; Wang *et al.*, 2000; Bertheke Post *et al.*, 2001; Croll *et al.*, 2001; Day *et al.*, 2001; Despres, 2001; Laitinen *et al.*, 2001; McCarthy *et al.*, 2001; Tyrrell *et al.*, 2001; Wright *et al.*, 2001; Alexy *et al.*, 2002; Gallagher *et al.*, 2002; Goldberg, 2002; Henderson *et al.*, 2002; Puyau *et al.*, 2002; Wang *et al.*, 2002; Webb, 2002; Fuentes RM, 2003; Jebb *et al.*, 2003; Livingstone & Black, 2003; Magarey *et al.*, 2003; Neumark-Sztainer *et al.*, 2003; Boreham *et al.*, 2004; Craigie *et al.*, 2004; Demory-Luce *et al.*, 2004; Department of Health Physical Activity Health Improvement and Prevention, 2004; Fletcher *et al.*, 2004; Fulkerson *et al.*, 2004; Gordon-Larsen *et al.*, 2004; Jebb *et al.*, 2004; Lake *et al.*, 2004a; Lake *et al.*, 2004b; Lobstein *et al.*, 2004; Neumark-Sztainer *et al.*, 2004; Rennie *et al.*, 2005; Ekelund *et al.*, 2006; Johannsson *et al.*, 2006; Lawlor & Chaturvedi, 2006; McCarthy *et al.*, 2006; Neumark-Sztainer *et al.*, 2006; Rennie *et al.*, 2006; Troiano, 2006; Wardle *et al.*, 2006; Butland *et al.*, 2007; Garnett *et al.*, 2007; Krebs *et al.*, 2007; Neumark-Sztainer *et al.*, 2007; Ward *et al.*, 2007)

<u>(Lawlor & Chaturvedi, 2006)</u>

(Livingstone & Robson, 2000)

(Story & Resnick, 1986)

(Department of Health, 1991)

(Watt & Sheiham, 1996; Neumark-Sztainer *et al.*, 1999)

(Story *et al.*, 1996)

(Food Standards Agency, 2003; Videon & Manning, 2003)

(O'Dea, 2003)

(Kelsey *et al.*, 1998)
(Neumark-Sztainer *et al.*, 2000)
(Hearn *et al.*, 1998)
(Baranowski *et al.*, 1999; Birch, 1999; Kratt *et al.*, 2000; Nicklas *et al.*, 2001)
(Lau *et al.*, 1990; Woodward *et al.*, 1996; Backman *et al.*, 2002; Lee & Reicks, 2003; Hanson *et al.*, 2005)
(Crawley & While, 1995)
(Huang & Volpe, 2004)
(McCullum & Achterberg, 1997)
(Chapman & Maclean, 1993)
(Twisk, 2003)

(Berenson *et al.*, 1998a)
(Srinivisan *et al.*, 1996; Twisk *et al.*, 1997)
(Freedson *et al.*, 1998)
(Nelson *et al.*, 1997)
(Fletcher, 2003)
(Food Standards Agency, 2002)
(Chan *et al.*, 1994)
(Office of National Statistics, 2000)
(Office of National Statistics, 1990)
(Chumlea & Guo, 1994)
(Garrow, 1981)
(Trost *et al.*, 1998)
(Trost *et al.*, 2001)
(Ekelund *et al.*, 2005)
(Sallis *et al.*, 1993)
(Michaud *et al.*, 1990)
(Weidner *et al.*, 1996)
(Braam *et al.*, 1998)
(Nelson *et al.*, 1994)
(Robinson *et al.*, 1997)
(Gerber *et al.*, 1997)
(Hill, 2006)
(Foster *et al.*, 2006)
(Webb, 2002)
(Dietz, 1997)
(Nunez *et al.*, 1997)

(Lean *et al.*, 1995)

(Corder *et al.*, 2007)

(Welk *et al.*, 2007)

(Singh *et al.*, 2008)

(Nelson, 1997)

(Molarius & Seidell, 1998)

(Lean, 2000)

(Guo *et al.*, 2002)

(Nelson, 2000b)

(Ebbeling *et al.*, 2002)

(Trost *et al.*, 2001)

(Harris *et al.*, 2000)

(Wills, 2005)

(McPherson *et al.*, 2007)

(Kopelman, 2007)

(Jebb, 1997; Jebb, 2007)

(Baranowski & Domel, 1994)

(James *et al.*, 2004)

(Nelson *et al.*, 2007)

(Ludvig *et al.*, 2001)

(Katzmarzyk *et al.*, 2001)

(Tiggemann, 2005)

(Willett, 1998)

(Lake & Townshend, 2006)

(Cusatis *et al.*, 2000)

(Gallagher *et al.*, 2005)

(Corder *et al.*, 2008)

(Atkins, 2003)

(Ekelund *et al.*, 2002)

(Ball *et al.*, 2001)

(Ortega *et al.*, 2007)

(Sallis *et al.*, 2000)

(Treuth *et al.*, 2005)

(Barasi, 2003)

(Noller & Callan, 1991)

(Goran, 1998)

(Rolland-Cachera *et al.*, 1987)

(Harnack & Schmitz, 2006)

(Wills, 2005)

(Ashwell, 2005)

(Nicklas *et al.*, 2003)

(Gregory *et al.*, 1990)

(Frank, 1991)

(Post *et al.*, 2001)

(Harris *et al.*, 2000)

(Friedman, 1997)

(Page & Fox, 1998)

(Ashwell, 1997)

(Trost & Pate, 1999)

(McGill *et al.*, 2000)

(Ferriera *et al.*, 2005)

(Cade *et al.*, 2002)

(Baker *et al.*, 2007)

(Engeland *et al.*, 2004)

(Field *et al.*, 2005)

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(Prentice & Jebb, 1995)

(McCarthy *et al.*, 2003)

(Utter *et al.*, 2003)

(Nader *et al.*, 2008)

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(Department of Health, 2008)

http://www.tradingstandards.gov.uk

(Bandini *et al.*, 1990)

(Bratteby *et al.*, 1998)

(Freedman *et al.*, 2004)

(Parsons *et al.*, 1999)

(Dallongeville *et al.*, 1998)

(Sweeting *et al.*, 2008)

(Larsson & Wolk, 2007)

(NHS, 2010)

(Craigie *et al.*, 2003)

(World Health Organization, 2005); ; (World Health Organization, 1995); (World Health Organization, 2003b; World Health Organization, 2003a)

(Birch, 1987)

(Hackett *et al.*, 1984); (Hackett *et al.*, 1982)

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(Bingham & Day, 1997); (Martinez, 2000); (Must & Tybor, 2005);(Willett, 1998)

(Food Standards Agency, 2001); (Lake *et al.*, 1997); (Must & Tybor, 2005)

(Gibson, 1990) (McCarthy *et al.*, 2003); (Johansson *et al.*, 1998);(Wang *et al.*, 2002)

(Cavadini *et al.*, 2000);(Johannsson *et al.*, 2006);(Stein *et al.*, 1991)

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Mr Trevor Doughty
Director of Children's Services
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NE61 2EF

4th January 2005

Dear Mr Doughty

Re: Northumberland Food Survey of Adolescents aged 16 to 17 years

I would like to inform you of a study that we hope to carry out over the next three years in four Northumberland high schools: Hirst High School, The King Edward VI High School, St Benet Biscop RC High School and Ashington High School.

In 2000, 424 children aged 11 to 12 years old, from seven schools in Northumberland (*Ashington Alexandra Middle School, Ashington Hirst Park Middle School, Chantry Middle School, Newbiggin County Middle School, Newminster Middle School, Seaton Hirst Community Middle Schoo*l, and *St Benedict's RC Middle School*) took part in the Northumberland Food Survey of the dietary intake of children in year 7.

This was the third survey in the series 1980, 1990 and 2000, which were undertaken by the University of Newcastle under the direction of Professor Andrew Rugg-Gunn. I have been involved since the 1990 study and have taken over guardianship of this work since Professor Rugg-Gunn's retirement in 2001.

These surveys give valuable data on the changing eating habits and body weight of children, which have been used throughout the UK and internationally. In addition, in 2000 a follow-up survey of the 1980 children, now aged 32 to 33 years, was carried out to investigate changes in dietary habits from childhood to adulthood.

I am delighted to enclose a copy of the scientific papers published from each of the 2000 studies which may be of interest to you. These have been published in the prestigious journals - British Journal of Nutrition and Appetite.

This work has created great interest, and as a direct result we have recently received funding from the Food Standards Agency for a study to follow up the children who took part in the 2000 survey now aged 16 to 17 years. Alison Hossack has been appointed to carry out this study.

The height, weight, waist and hip circumference and body composition (using electrical scales for measuring body fat) of the young people of this study will be measured, and they will be asked to record their dietary intake by completing two 3-day food diaries; complete a questionnaire regarding their eating habits and perception of food choice; and record their level of physical activity using a small electrical device such as an accelerometer (similar to a pedometer).

All university workers in contact with these young people will have prior Criminal Records Bureau (CRB) clearance.

We will be contacting the relevant High Schools (*Hirst High School, The King Edward VI School, St Benet Biscop Catholic High School and Ashington High School)* to arrange meetings at the end of January.

If you would like to discuss the details of the study or would like any further information please do not hesitate to contact either myself on 0191 222 5276 or Alison Hossack on 0191 282 4009.

Yours sincerely

Dr A Adamson BSc, SRD, PhD, RPHNutr.
Lecturer in Nutrition, Project supervisor

Enc.

Mrs C Black
Newbiggin County Middle School
Cleveland Avenue
Newbiggin-by-the-sea
Northumberland
NE64 6RR

23rd November 2004

Dear Mrs Black

You will remember that during 2000, your school very kindly took part in the Northumberland Food Survey of the dietary intake of children in year 7. Emma Fletcher collected these data and was made very welcome in your school, thank you.

This was the third survey in the series 1980, 1990 and 2000, originally begun by Professor Andrew Rugg-Gunn of the University of Newcastle. These surveys give valuable data on the changing eating habits and body weight of children, which have been used throughout the UK and internationally.

I am delighted to enclose a copy of the first scientific paper to be published from the 2000 study. This has been published in the prestigious British Journal of Nutrition. I have also enclosed a brief summary of the findings of the paper, which may be useful to you.

You may be interested to know that Emma Fletcher graduated with her PhD as a result of her study. Professor Andrew Rugg-Gunn retired two years ago but remains involved. I now have the role of principal researcher for these datasets. I was responsible for collecting the 1990 survey data and supervised the 2000 survey.

This work has created great interest, and as a direct result we have recently received funding from the Food Standards Agency for a study to follow up the children who took part in the 2000 survey. Alison Hossack has been appointed to carry out this study.

Our first task is to find these 'children' who will now be young people aged 16-17 years. We hope to be able to ask for your help with this by telling us which High school the children participating in the study went on to. I hope you will allow Alison to contact you in December to help trace the children of the 2000 study, and of course thinking further to the future, in time for a fourth survey in 2010.

Thank you once again to your school for participating in this work.

With very best wishes

Dr A Adamson BSc, SRD, PhD, RPHNutr.
Lecturer in Nutrition

Enc.

2000 - 2005 Food Survey
NYPD
Northumberland Young Peoples Diet

Hello again!

In 2000, you were kind enough to take part in a survey of your diet. You may remember that you filled in two food diaries during year seven of middle school, and Emma Fletcher came to talk to you about what you had eaten.

The great news is that we are carrying out another similar survey to find out what you are eating now, and we would really like you to take part. It is really important that as many people who took part last time, do so again - Every person is very important to the success of the study.

What will I have to do?

The study will involve you as follows:

- Completing a three-day food diary twice during the year 2005. This diary will be the same as the one you used when you were in middle school. We don't need food to be weighed; just a description of the food is enough. Alison Hossack, a nutritionist will give the diary to you and discuss it with you.
- We would like you to complete an electronic questionnaire about the food you eat and your level of physical activity.
- We would also like you to measure your level of physical activity, using an electrical device such as an accelerometer (similar to a pedometer).
- On one occasion we would like to measure your height, weight, waist & hip circumference and body composition (what makes up your body).

At the end of the study

As a thank you for completing all aspects of the study, we will give you a £10 gift voucher and will enter you into a prize draw to win one of five prizes, each to the value of £150.

This is very exciting, as you would be providing information that has never been collected before. It gives us the chance to look at how what we eat changes as we get older. This is really important as it could be used to develop government health guidelines in the future.

Your involvement in this new project would be as important as it was in 2000. We hope you are still interested in helping us.

What will happen to the results of the study?

The results of this study will be written and published in scientific and medical journals, and will be presented at meetings and conferences. **Very importantly**, we understand that we are collecting personal information about you that you would prefer others not to know. **No one will be personally identified within the results.** We will use **numbers not names**, and all personal details will be kept **strictly confidential**.

Contact for further information?

If you would like any further information about the study, please feel free to phone Alison Hossack on 0191 222 3829/07801097239.

What happens now?

Thank you for reading this. We really hope you will decide to take part in this important research. If you do, please read and sign the consent form enclosed, and return it to us in the envelope included. Please hand the envelope to your school office for us to collect.

I would point out that there is no obligation to take part, but I very much hope that you will help us again in this study. If you do not want to take part and would rather we did not contact you again, please use the enclosed consent form to indicate this and return it to us in the envelope included. Please hand the envelope to your school office for us to collect.

Thanks again for your time and consideration and we look forward to receiving your consent form.

Best wishes

Dr Ashley Adamson

Lecturer in Nutrition, Project Supervisor

Enc.

I have read the letter of invitation and have had the opportunity to ask questions about it.

I **would / would <u>not</u>** like to volunteer to take part in this study.
(please delete as applicable)

PLEASE COMPLETE THIS SECTION

SURNAME………………………………………………FIRST NAME…………………………………………………………………

SURNAME *as at middle school (if different)*………………………………………………………………………

ADDRESS………

……

……………………………………………………………………………**POST CODE**…………………………………………………………

TELEPHONE NUMBER…………………………………………MOBILE NUMBER……………………………………………

EMAIL ADDRESS……

Please sign here……………………………………………………………………………………………………

Parent/guardian consent………………………………………………………………………………………

If you <u>do not</u> wish to take part in this study, and prefer that we did not send you any further information please fill in ***<u>name and postcode only above</u>*** ***and*** ***<u>tick this box.</u>*** ☐

<u>Please return the form to us in the enclosed envelope.</u> Thank you

---

NB: ***Completing and returning this form <u>does not</u> put you under any obligation to take part in the study, and should you wish to take part in the study you are free to leave at any time.***

2000 - 2005 Food Survey
NYPD
Northumberland Young Peoples Diet

WANTED…

…Anyone in **YEAR 12** who hasn't returned their forms for the food survey!

✓**We really would like you to take part, so much, we are giving everyone who completes the survey a £10 voucher and entering them into a draw for a prize to the value of £150 for taking part.**

✓**Lost your form ?** – You can get a new consent form from your school reception or contact Alison

✓Fancy some feed back on how you eat…

…This will be available if you complete the study

SO HURRY AND GET YOUR FORMS RETURNED

Please return the form (even if you CAN'T take part)

Alison Hossack

Mobile number 07801097239

Human Nutrition Research Centre
UNIVERSITY OF
NEWCASTLE UPON TYNE

Day & Date...Sunday 10th July...		Start each day	on a new sheet				Volunteer ID......1010......
Time	**Food & drink** include: Brand name, flavour and packet weight *Enter each food item on a new line*	**Cooking method** e.g. fried, grilled, poached, etc.	**Amount eaten excluding leftovers.** e.g. cup, slice, teaspoonful, portion of family meal	Office use	**Food Photo** Office use	**Weight** Office use	**Food Code** Office use
10:40am	water (filtered)		1 medium glass		G19I	200ml	17377 ✓
	Tracker cereal bar		2 bars		✓	74g	21006 ✓
	Coffee (carte noire)		1 large mug		G19G	284ml	17161 ✓
12:00	" water (filtered)		1 medium glass		G19I	200ml	17377 ✓
	The Real McCoys - Salt and vinegar		1 bag		✓	55g	17139 ✓
1:15pm	filtered water		1 large glass		G19H	300ml	17377 ✓
	Vegetable soup		1 bowl		787	369g	17283 ?
	brown bread bun		1 bun		G29	55g	11478 ✓
3:00pm	Bart Simpson, Eat my shorts biscuits		5		✓	55g	11506 ?
3:45pm	filtered water		2 small glasses		G19I	400ml	17377 ✓
	Bart Simpson, Eat my shorts biscuits		6		✓	66g	11506 ?
6:05pm	Spagetti bolognaise	Recipe	~~very little~~ medium		31 342	55g 70g	11453 14352 ✓
	High juice, tropical squash (diluted)		3 medium glass		G19I	~~200ml~~	17198 ✓
	~~mince~~		~~medium portion~~				
	blueberry and raspberry muffins	RECIPE	2	From Hom. & friends	✓	85g(2)	11261 ✓

Have you taken any supplements or non prescribed medication e.g. Vitamin tablets, etc. Please specify...

....

....

Time wearing your actigraph.

Time on: 10:39am	**Time on:**	**Time on:**	**Time on:**
Time off: 11:04pm	**Time off:**	**Time off:**	**Time off:**
Reason: bed	**Reason:**	**Reason:**	**Reason:**

ACTIGRAPH ™ PROTOCOL

Collection of Information

The participants will be asked to wear the Actigraph for the same period as completing each food diary. Validation of the Actigraph data in this study will be by (1) comparing measured energy expenditure (EE) with recorded energy intake (EI). EI will be recorded using 2 x 3-day dietary diaries; (2) comparing measured EE with self reported physical activity. Self reported physical activity will be recorded using an electronic questionnaire. Each participant will asked to record the time period when they wear the monitor at the bottom of each days food intake. The participant will be interviewed on the fourth day along with their food diary in order to clarify information. Purpose built programmes will be adapted for use in this study.

Initialisation of Actigraph Monitors

Prior to use, each monitor is to be initialised using the Actigraph software programme.

- Ensure the Actigraph reader is connected to the computer and switched on at the mains (this is indicated by a green light on the front of the reader).
- Open the Actigraph programme from the computer desktop by clicking on the Actigraph icon.
- Place a monitor in the reader – printed face down, reader circle to the front (over the metal plate). Correct installation is indicated by a red flashing sequence between the monitor and reader.
- Initialise the monitor by highlighting the “initialize” tab on the left of the Actigraph programme.
- Check that the battery indicator is not highlighted in red (should be green or yellow – the number represents the number of battery hours remaining and therefore should not be a minus figure).
- For the purpose of this study, each monitor is set to 1 minute epochs ( ).
- The date and start time is when the participant is due to be given the monitor.
- Participant ID is that which is found on the participant consent form.
- Press OK to initialise.

Downloading Actigraph data

- Open the Actigraph programme as above
- Place the monitor in the reader as above
- Click on the “stop Actigraph” tab on the left of the programme, then choose “stop and download” from the drop down box.
- Save the file as “ID(no.)” in the relevant file (i.e. school).
- Confirm by pressing “ok” and “ok” again to process the record. After downloading press “yes” to view file: the downloaded data will open in an Actigraph Graph file.

- Close file and from the left hand menu click the “Analyse” tab, then “Activity from Data File”. Open the appropriate file (i.e. school) and “save”. Press “yes” to view file in an excel spreadsheet.

<u>Instructions for use</u>

- The monitor should be placed on the front right hip (for standardisation)
- The two circles (or groove on older models) on the front face should be facing upwards.
- The back of the monitor (unprinted) is be placed against the skin under the participants clothing.
- The belt should be fastened tight enough to prevent movement of the monitor (adjustment can be made by tightening or loosening the strap).
- The participant is asked to wear the monitor from time of delivery to time of collection (varying from 4 to 5 days), removing for bed, or bathing.
- The participant is asked to record on the bottom of each day of the food diary, the time the monitor is put on, when it is taken off and the reason it was taken off.

<u>Methods of explaining the task</u>

  - A short visit at the time of delivery of the food diary to present the respondent with the activity monitor will comprise of an introduction to the aims of the project:
  - How we are planning to compare their energy intake (from the food diary) with their energy output (from the monitor).
  - Motivate and enthuse the participants.

- Each participant will be provided with an Actigraph, initialized* specifically for each participant.

- Participants who are still at school will be instructed in small groups. An explanation and details of the data collection will be given in the participating high schools. Participants traced, who are no longer attending high school in the Northumberland area, will be instructed in their own home, place of work or at a place of their choice.

- The participants will be asked to wear the monitor from delivery until collection, however, they will be asked only to record when they wear the monitor on the 3 days they complete their food diary; these days are written on the front of the diary. The three days recorded in each diary are consecutive but the days of the week will be chosen by convenience and the second diary will be completed for different days from the first diary.

- On the fourth day, interviews will take place in the schools or at a place convenient to the participant to clarify the recording time of the monitor for the three days. The date and time of the interview is recorded on the inside cover of the diary. These interviews are to be as standardised as possible.

- The second food diary will be completed on different days to the initial recording. As before, the participants will be interviewed individually on the fourth day of completing the diary.

* Refer to paragraph 2 for instructions on initialisation.

2000 - 2005 Food Survey

NYPD

Northumberland Young Peoples Diet

Questionnaire

All of the questions in this questionnaire are designed to provide the researcher, Alison Hossack, with an insight into what influences you (your age group) to eat the type of foods you eat. The answers to these questions may provide valuable data to help future Government health programmes.

All data is confidential and no person will be named in any future publication(s).

Part 1: About you

1. Please choose which statement best describes your living circumstances.
Please tick one box below

Living alone	☐
Living with others	☐

Who is this person(s)?
Please tick as many boxes as apply

Parent(s)/guardian	☐	
Brother(s)/sister(s)	☐	
Spouse/partner	☐	
Children	☐	
Other (please specify)	☐	

2. Please choose which statement(s) best describe your circumstances.
Please tick as many boxes that apply below

I am still at school (6th form)	☐	
I am at college (further education) (please specify)	☐	
I work full time (please specify)	☐	
I work part time (please specify)	☐	
I am unemployed	☐	
Other (please specify)	☐	

3. Who is the person that earns the most in the house where you live?
Please tick one below

My father earns the most	☐	
My mother earns the most	☐	
My partner earns the most	☐	
I am the person that earns the most	☐	
Other (please specify)	☐	

3a. **What is the name or title of this persons job? E.g. primary school teacher, state registered nurse, car mechanic, television service engineer, benefits assistant etc.**
Please write your answer in as much detail as possible in the box below

3b. **What work does this person do most of the time in their main job?**
Please write your answer in as much detail as possible in the box below

3c. **Does this person supervise any other employees?**
A supervisor or foreman is responsible for overseeing the work of other employees on a day to day basis.
Please tick one box below

Yes	☐
No	☐
Don't know	☐

4. **What is your country of birth?** *Please tick one box in* ***column A***
What is your ethnic group? *Please tick one box in* ***Column B***

Column A

- A ☐ England
- B ☐ Northern Ireland
- C ☐ Republic of Ireland
- D ☐ Scotland
- E ☐ Wales
- F ☐ Any other
  Please specify

Column B

A **White**
- ☐ British
- ☐ Irish
- ☐ Any other white background
  Please specify

B **Mixed**
- ☐ White and Black Caribbean
- ☐ White and Black African
- ☐ White and Asian
- ☐ Any other mixed background
  Please specify

C **Asian or Asian British**
- ☐ Indian
- ☐ Pakistani
- ☐ Bangladeshi
- ☐ Any other Asian background
  Please specify

D **Black or Black British**
- ☐ Caribbean
- ☐ African
- ☐ Any other black background
  Please specify

E **Chinese or other ethnic group**
- ☐ Chinese
- ☐ Any other
  Please specify

Part 2: About you and your health

5. Do you smoke?

Please tick one box below

Yes, I smoke daily	☐	⇨ Please answer question 5a
Yes, I smoke occasionally	☐	⇨ Please answer question 5a
No, but I used to smoke	☐	⇨ Please answer question 5a
No, I have never smoked	☐	⇨ Please go to question 6

5a. If yes, how much on average do (did) you smoke per day?

Please write in the amount for each; if none write '0'

Cigarettes ☐
Cigars ☐
Ounces tobacco ☐

6. How strongly do you agree with this statement?
'Exercise is important to me'

Please tick one box below

☐	☐	☐	☐	☐
Strongly disagree	Disagree	neither agree nor disagree	Agree	Strongly agree

7. At least once a week, do you take part in any regular activity, such as jogging, cycling etc., long enough to work up a sweat?

Please tick one box below

Yes ☐
No ☐
If yes, how many days per week? ☐

8. Over the next month, how confident are you that you are able to be physically active at least three times per week?

Please circle one number below

Very confident 1 2 3 4 5 Not at all confident

9. How strongly do you agree with the statement?
'I do more exercise now than when I was 12 years old'

Please tick one box below

☐	☐	☐	☐	☐
Strongly disagree	Disagree	neither agree nor disagree	Agree	Strongly agree

10. Each of the following statements are about your health, please identify how strongly you agree or disagree with the statements by *ticking* <u>*one*</u> *box next to* <u>*each*</u> *of the statements below*

	Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree
If I get ill it is my own behaviour which determines how soon I get well again.						
No matter what I do, if I am going to get ill, I will get ill.						
Having regular contact with my doctor is the best way for me to avoid illness.						
Most things that affect my health happen to me by accident.						
Whenever I don't feel well, I should consult a medical professional.						
I am in control of my health.						
My family has a lot to do with my becoming ill or staying healthy.						
When I get ill, I am to blame.						
Luck plays a big part in determining how soon I will recover from an illness.						
Health professionals control my health.						
When I stay healthy, I'm just lucky.						
My physical well-being depends on how well I take care of myself.						
If I take care of myself, I can avoid illness.						
Whenever I recover from an illness, it's usually because other people (e.g. doctors, nurses, family, and friends) have been looking after me.						
Even when I take care of myself, it's easy to get ill.						
If it's meant to be, I will stay healthy.						
If I take the right actions, I can stay healthy.						
Regarding my health, I can only do what my doctor tells me to do.						

Part 3: About your food choice

11. Who <u>most</u> influences what you eat?
Please tick <u>one</u> box below

- Parent(s)/guardian ☐
- Brother(s)/sister(s) ☐
- Friends ☐
- Spouse/partner ☐
- Child/children ☐
- Someone else (Please state who) ☐ ____________
- No one but myself ☐

12. Who does the food shopping for your household?
Please tick <u>one</u> box below

- Parent(s)/guardian ☐
- Brother(s)/sister(s) ☐
- Friends ☐
- Spouse/partner ☐
- Someone else (Please state who) ☐ ____________
- No one but myself ☐

13. Do you eat a particular kind of diet e.g. vegetarian, weight control, Halal, Gluten free, etc.?
Please tick **Yes** <u>or</u> **No** *in the box below.*

No ☐ ⇨ Please go to question 14
Yes ☐ Please tick the boxes that apply to you

- ☐ Gluten Free
- ☐ Halal
- ☐ Kosher
- ☐ Vegan
- ☐ Vegetarian
- ☐ Wheat free
- ☐ Weight gain
- ☐ Weight reducing
- ☐ Other Please state ____________

14. How often do *you* buy something to eat? Please include sweets and snacks that you buy for yourself?
Please tick one box.

Every day	☐	Please state how many times a day?	☐
Every other day	☐	Please state how many days per week?	☐
School/college days only	☐		
Weekends only	☐		
Other (please specify)	☐		

15. Where do you usually buy something to eat?
Please tick the boxes next to the places where you buy MOST of your food.

Supermarket	☐	
Small local shops	☐	Please specify
Mobile Van	☐	
School/college canteen/cafe	☐	
School/college vending machine	☐	
Other (please specify)	☐	

16. Do you read the labels of food packaging (front or back)?
Please tick one box below

Yes ☐ ⇨ Please answer question 16a
No ☐ ⇨ Please go to question 17

16a. What information do you look for on the label?
Please tick all the boxes that apply

Amount of energy/calories	☐	
Amount of carbohydrate	☐	
Amount of protein	☐	
Amount of fat	☐	
Amount of salt	☐	
Amount of sodium	☐	
Allergy advice – please state	☐	
Other – please state	☐	

17. How strongly do you agree with this statement?
'Eating healthily is important to me'
Please tick one *box below*

Strongly disagree	Disagree	neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

18. Over the next month, how confident are you that you are able to eat healthily?
Please circle one number *below*

Very confident 1 2 3 4 5 Not at all confident

19. Thinking about what you eat now, how many portions of fruit and vegetables (*canned fresh or frozen*) do you eat each day?
Please tick ***one*** box *below*

Five or more portions per day	☐
4 portions per day	☐
3 portions per day	☐
2 portions per day	☐
1 portion per day	☐
Every other day	☐
None	☐

20. Over the next month, how confident are you that you are able to eat at least five portions of fruit and vegetables per day?

Please circle <u>one number</u> *below*

Very confident 1 2 3 4 5 Not at all confident

Part 4: About changes in your food choice since you were 12 years old

21. **How much do you think your eating habits have changed since you were 12 years old?**
Please tick one box below

☐	No changes have occurred	⇨ Please go to question 24
☐	Small changes have occurred	⇨ Please answer questions 22 and 23
☐	Major changes have occurred	⇨ Please answer questions 22 and 23

22. **Has your intake of the food items listed below changed from when you were 12 years old?**
Please tick one box in each row and add your reasons

	More often now	Less often now	No change	What are the reasons for this?
Fruit	☐	☐	☐	
Vegetables	☐	☐	☐	
Red meat	☐	☐	☐	
White meat	☐	☐	☐	
Dairy	☐	☐	☐	
Confectionery (sweets & chocolate)	☐	☐	☐	
Breakfast cereals	☐	☐	☐	

23. If your eating patterns have changed, what has influenced these changes?
Please tick *as many of the boxes next to the things listed below that you think may explain a change in your eating habits?*

	Reason for change in eating habits
☐	Change in the food that you like or dislike
☐	Your enjoyment of food
☐	Concerns about safety/content of foods e.g. food scares/organic foods
☐	The type and variety of foods available
☐	Price of foods
☐	Advertising & marketing of food products (promotional offers)
☐	I now have freedom over the foods that I eat
☐	Desire to maintain health
☐	Moving away from the family home
☐	Your body weight
☐	Ill health/special diet, in self/family members or friends
☐	Living with children
☐	Living with spouse or partner
☐	Religion
☐	Ethical/political concerns
☐	The knowledge you have about food
☐	The skills that you have to prepare/cook food
☐	The time you have available to prepare and cook food
☐	Travel and experiencing new foods
☐	Money available to spend on food
☐	The type of job that you have
☐	Lack of available kitchen equipment
☐	Work location and availability of food outlets in location
☐	Ease of shopping for food
☐	Other – please state

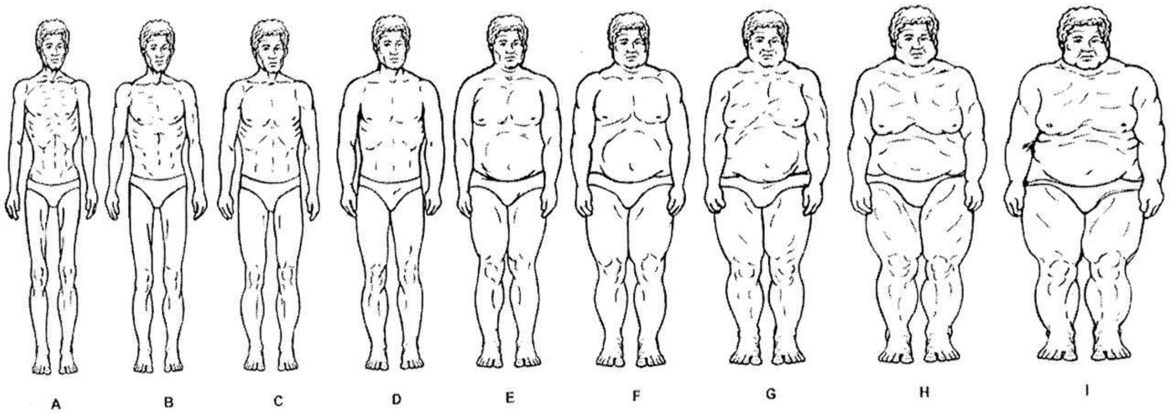
Part 5: About you and your body image

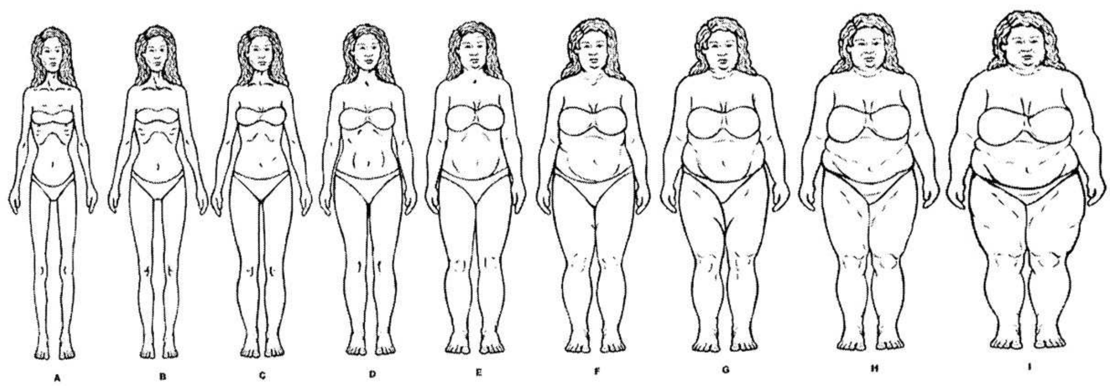
24. Thinking about your weight now, how would you describe yourself?
Please tick one box below

☐	☐	☐	☐	☐
Very Underweight	underweight	normal	overweight	very overweight

25. Please look at the figures below and answer questions a and b,
a) which one do you think represents your shape now?
Please tick one box below.
b) which shape would you like to be?
Please tick one box below.

Figure	A	B	C	D	E	F	G	H	I
9a) Please tick one box									
9b) Please tick one box									



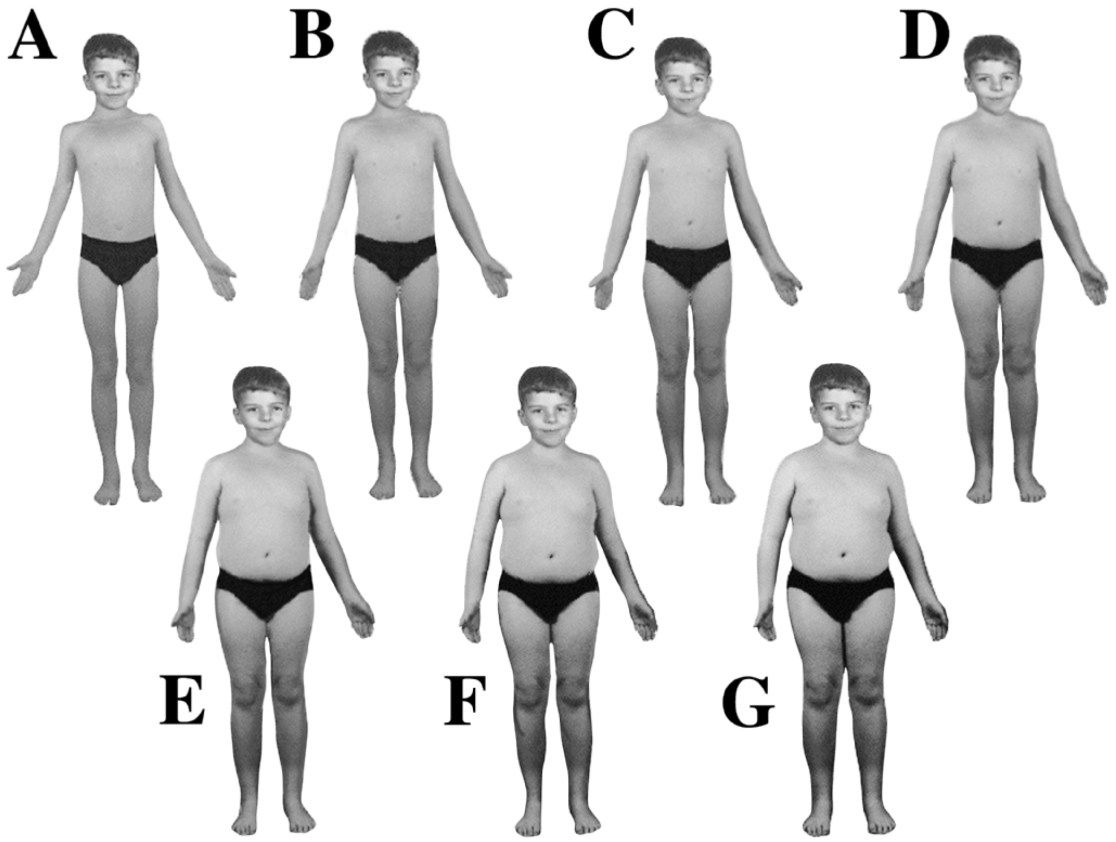


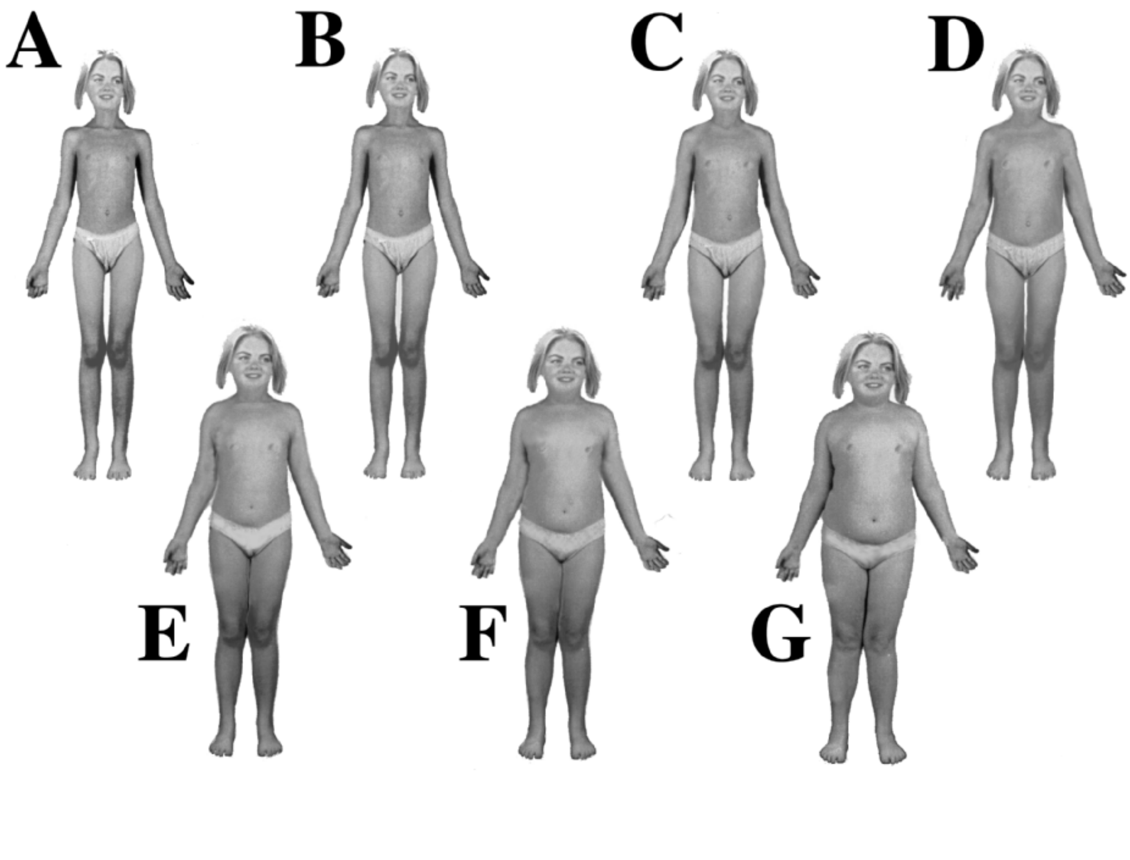
26. **Thinking about your weight as a 12 year old, how would you describe yourself?**
Please tick one box below

☐	☐	☐	☐	☐
Very Underweight	underweight	normal	overweight	very overweight

27. **Please look at the figures below, which one do you think represents your shape at 12 years of age?**
Please tick one box below (male or female).

Figure	A	B	C	D	E	F	G
Please tick one box							


A
B
C
D
E
F
G


A
B
C
D
E
F
G

28. **How strongly do you agree with this statement?**
'Maintaining a healthy body weight is important to me"
Please tick one *box below*

☐	☐	☐	☐	☐
Strongly disagree	Disagree	neither agree nor disagree	Agree	Strongly agree

29. **Over the next six months, how confident are you that you are able to maintain a healthy body weight?**
Please circle one number *below*

Very confident 1 2 3 4 5 Not at all confident

You have finished
Thank you for taking the time to complete this questionnaire.

Alison Hossack

TANITA™ BODY FAT ANALYSIS PROTOCOL

Collection of Information

- Height of participant, measured in cm using a Soehnle digital height measuring unit (ref).
- Age of participant.
- Level of activity of participant i.e. *standard* or *athletic* (athletic = more than 10 hours of intense physical activity per week and a resting heart rate of 60 beats per minute or less). (REF Tanita).

Instructions for use

- Place the weighing platform on a level surface and align using the spirit level (refer to manufacturers instruction booklet).
- Connect reader to power socket and place on suitable surface (such as a table).
- Turn on the power.
- Set print reader to read measurements only (not goal)
- Enter clothes weight - allow 2kg for clothing (refer to manufacturers instruction booklet)
- Select body type.
- Enter age
- Enter height (cm)
- Allow platform to stabilise.

Methods for measuring participants

Participants should:

- Remove socks and shoes
- Remove clothing to a single layer (i.e. to shirt / t-shirt and trouser / skirt).
- Remove additional loose items such as money, keys, mobile phones etc
- Step on the weighing platform with:

    Clean bare feet so they touch the electrodes
    Knees straight, hands by their side.

Table of variables considered in the prediction of anthropometric outcomes at age 17 years (General linear model)

Sex*	Log BMI17 (p-value)	R^2	% Body Fat (p-value)	R^2	LogWC (p-value)	R^2	WHR (p-value)	R^2
Social Group (11)	0.435	0.0%	0.000	36.2%	0.000	12.1%	0.000	25.6%
Log BMI 11	0.000	50.1%	0.000	61.6%	0.000	48.2%	0.000	36.8%
Alcohol 11	0.430	-1.1%	0.131	10.8%	0.113	12.2%	0.024	25.5%
% CHO 11	0.618	-0.5%	0.000	35.5%	0.000	9.4%	0.000	24.7%
% Fat 11	0.684	-0.7%	0.000	36.4%	0.000	9.4%	0.000	24.1%
EI 11	0.010	3.8%	0.000	35.2%	0.000	11.8%	0.000	24.0%
% Protein 11	0.693	-0.7%	0.000	35.8%	0.000	9.1%	0.000	23.6%
% Fat 17	0.211	0.6%	0.000	34.3%	0.000	9.2%	0.000	23.5%
EI 17	0.143	1.0%	0.000	33.6%	0.000	11.1%	0.000	23.2%
% Protein	0.885	-0.9%	0.000	36.5%	0.000	8.0%	0.000	22.9%
Log Counts/Day	0.675	-0.7%	0.000	38.5%	0.001	6.7%	0.000	22.8%
% CHO 17	0.311	0.2%	0.000	36.0%	0.000	8.5%	0.000	22.7%
Log Counts/hr	0.946	-1.2%	0.000	38.0%	0.002	6.5%	0.000	22.3%
Alcohol 17	0.062	2.8%	0.000	21.3%	0.198	1.0%	0.044	3.3%

FOOD DIARY PROTOCOL

Collection of Dietary Information

The participants will be asked to complete two 3-day dietary diaries, which will be collected during a 12 - month period; completion of each dietary record being 5 to 7 months apart. This method has been used extensively (Hackett et al 1984; Adamson et al 1992; Fletcher et al. 2004) and the validity of the method and reliability of the data measured in children (Hackett et al 1983, 1985; Adamson et al 1992). Validation of dietary recording in this study will be by (1) comparing recorded energy intake with estimated energy needs based on predicted BMR (Bingham et al 1984; Schofield et al 1985) and (2) measuring physical activity – comparing recorded energy intake (EI) with measured energy expenditure (EE). EE will be measured using activity monitors. Each subject will be interviewed on the fourth day in order to clarify information and determine the weight of foods eaten (with the aid of collected packaging, food tables, and the use of a photographic atlas). Purpose built programmes will be adapted for use in this study. For foods not listed in the food tables the best available data will be used to create a new food code. In some cases this will require foods to be analysed for specified nutrients.

Methods of explaining the task

- A short visit to present the respondent with the food diary will comprise of an introduction to the aims of the project:
- How we are planning to compare their diet, then and now.
- Stress the importance of having a true picture of what they *normally* eat.
- Motivate and enthuse the participants.

- Each participant will be provided with a new A5 size food diary, designed for this particular project containing instructions for collection of dietary data and a sample page. A logo specific to this project was designed to be used on the diary and in all further correspondence with the participants (appendix 5).

- Participants who are still at school will be instructed in small groups. An explanation and details of the dietary collection will be given in the participating high schools. Participants traced, who are no longer attending high school in the Northumberland area, will be instructed in their own home, place of work or at a place of their choice.

- The participants will be asked to record *all foods* they have eaten, including snacks and alcohol etc, with as much detail as possible, including the time food was eaten, weights, brand names, cooking methods, and estimated portion. They are to be supplied with a university plastic bag to keep food packaging.

- The participants will be asked to complete the first diary for three days; these days are written on the front of the diary. The three days recorded in each diary are consecutive but the days of the week will be chosen by convenience and the second diary will be completed for different days from the first diary.

- On the fourth day, interviews will take place in the schools or at a place convenient to the participant. This first interview will comprise of a clarification of the foods recorded in the diary for the three days, the date and time of which is recorded on the inside cover of the diary. Portion sizes will be estimated with the use of a photographic food atlas. These interviews are to be as standardised as possible.

- The second food diary will be completed on different days to the initial recording. As before, the participants will be interviewed individually on the fourth day of completing the diary.

- Following the conclusion of the second food diary interview, all the participants will have their weight, height, waist and hip measurements recorded in triplicate. These will be recorded on the back of the food diary in a table. Feedback should be kept minimal at this stage regarding their eating habits, diet, or anthropometry.

- Dr Adamson will oversee the collection of the above dietary data.