EFFECTS OF CONSUMING COMPARED WITH OMITTING BRAKFAST ON DIET AND PHYSICAL ACTIVITY IN ADOLESCENT GIRLS

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by

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ABSTRACT

Epidemiological data has demonstrated that regular breakfast consumption is associated with favourable daily dietary intakes and reduced obesity risk in children and adolescents. There is also some evidence that regular breakfast consumers have higher levels of physical activity when compared with breakfast skippers. Therefore, it is of concern that breakfast skipping is particularly common among adolescent girls. However, the observational data on breakfast, diet and physical activity remains inconclusive and fails to infer causality. Therefore, the aim of this study was to experimentally examine the effects of consuming compared with omitting breakfast on diet and physical activity in adolescent girls. A sample of 33 girls (24 used in final analyses) aged 12-15 completed three, 3-day trials: habitual breakfast, no breakfast and high-energy breakfast. The participants' dietary intakes were assessed using 3-day food diaries (and digital photography) and physical activity was measured with accelerometry. There was no main effect of trial on energy intake after breakfast (P=0.49), fruit and vegetable (P=0.21) and snack consumption (P=0.33). There was a significant main effect of breakfast condition on total daily energy intake (P=0.001) and on energy consumed from fat (P=0.001) and carbohydrate (P=0.001) when expressed as percentages of total daily energy intake. Daily energy intake was significantly higher in HEB compared with NB (P=0.001) and CON (P=0.002). Less energy from fat was consumed in HEB compared with CON (P=0.001) and NB (P=0.001), and more energy from carbohydrate was consumed in HEB compared with CON (P=0.001) and NB (P=0.001). There was no main effect of breakfast on time spent in sedentary (P=0.41), light (P=0.44), moderate (P=0.34) and vigorous (P=0.67) physical activity. Overweight and non-overweight adolescent girls did not compensate by consuming more energy or being less active for the remainder of the day when omitting compared with consuming breakfast consisting of ~475 kcal for three days.

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Master of Science by Research at the University of Bedfordshire.

It has not been submitted before for any degree or examination in any other University.

Name of candidate: Signature:

Date:

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BMI	Body mass index
CCK	Cholecystokenin
CHO	Carbohydrate
CON	Control
ES	Effect size
GI	Glyceamic index
GLP-1	Glucagon-like peptide 1
HEB	High-energy breakfast
HGI	High glycaemic index
LGI	Low glycaemic index
MGI	Moderate glycaemic index
NB	No breakfast
NO	Non-overweight
OW	Overweight
PPY	Peptide YY
SD	Standard deviation
RTEC	Ready-to-eat-cereal

1 Introduction

Obesity is a major contributor to cardiovascular disease, diabetes as well as some cancers (Frieden et al., 2010) and represents one of the major problems in public health and an economic burden (Reilly et al., 2011) today with the prevalence of obesity continuing to rise (Timlin et al., 2008). Health problems associated with being overweight and obesity cost National Health Services (NHS) more than £5 billion every year (Scarborough et al., 2011). Childhood obesity has now reached epidemic levels with the Health Survey for England (HSE) reporting that 33% of 2 to 15 year old boys and girls in 2013 were classified as overweight or obese. Increased adiposity and obesity occurs as a result of sustained positive energy balance which is achieved by increased energy intake and/ or decreased energy expenditure (Troiano et al., 2000). Various factors such as poor dietary habits, for instance excessive consumption of high density energy foods and decreased consumption of nutrient rich food such as fruits and vegetables, and insufficient activity can promote this shift towards positive energy balance and thus lead to overweight and obesity in children (Frieden et al., 2010). It has been reported that, of boys and girls aged 5 to 15 in the UK, only 16% and 20 % respectively met the "5-a-Day" recommendation for fruit and vegetable consumption (3 portions on average), and only 20% of boys and 16% of girls met current guidelines for children and young people of at least one hour of moderately intensive physical activity per day (HSE, 2013). With the various lifestyle factors related to nutrition and physical activity that contribute to improved weight status and health outcomes, one such factor, breakfast, is often considered to be 'the most important meal of the day' and a key component of a healthy diet (Tolfrey and Zakrzewski 2012, Szajewska and Ruszczynski 2012). Research has indicated that breakfast may be an effective way of managing obesity and enhancing nutrient intakes in children and adolescents (young people). Children and adolescents who regularly consume breakfast (breakfast eaters) are more likely to lead a healthy lifestyle and make healthier choices in general (Sandercock et al., 2010, Szajewska and Ruszczynski, 2012). Despite such benefits, breakfast consumption has decreased among children and adolescents over recent decades, particularly in adolescent girls (Timlin et al., 2008).

Daily breakfast consumption has been demonstrated to contribute to positive health outcomes, such as improved Body Mass Index (BMI), in young people. Many, but not all, cross-sectional and longitudinal studies have repeatedly demonstrated an inverse relationship between breakfast consumption and BMI, as well as other markers of adiposity, in children and adolescents (Rampersaud et al., 2009, Szajewska and Ruszczynski, 2012). In particular, ready-to-eat-cereal (RTEC) that contain low glycemic index (LGI) carbohydrates and are rich in fibre (Tolfrey and Zakrzewski, 2012) may play an important role in meeting recommended nutrient intakes and reducing obesity risk for the young population (Deshmukh-Taskar et al., 2010). However, results from previous longitudinal studies remain inconclusive and fail to infer the cause-and-effect relationship between breakfast and weight gain. Nevertheless, the higher risk of obesity in breakfast skippers suggests that these individuals have higher daily energy intakes or lower daily energy expenditures, resulting in a sustained positive energy balance, when compared with breakfast consumers.

Although breakfast skippers are more likely to be overweight or obese, there is some evidence that their daily energy intake is either not different (Dubois et al., 2009), or lower than of those who regularly eat breakfast (Barton et al., 2005, Berkey et al., 2003, Timlin et al., 2008). Unfortunately, only one experimental study appears to have examined the effects of breakfast on subsequent energy intake in children (Kral et al., 2011). The results indicated that breakfast omission resulted in increased feelings of hunger, but not increased energy intake throughout the day when compared with breakfast omission. However, the results were obtained on a single occasion under laboratory conditions, and the sample was limited to a normal-weight 8-10-year old children. Epidemiological evidence indicates omitting breakfast has been reported to be associated with various health compromising behaviours and unfavourable lifestyle choices (Keski-Rahkonen et al., 2003). It has been found that children and adolescents who omit breakfast consume greater energy from snacks, are more likely to skip other meals (lunch and dinner) than habitual breakfast eaters (Sjöberg et al., 2003), and compensate missing calories through eating later in the day, resulting in lower diet quality and poor nutrient intake (Dubois et al., 2008). Furthermore, breakfast skippers consume fewer servings of fruit and vegetables (Arora et al., 2012). However, again, the relationships between breakfast consumption and snack or fruit and vegetable consumption have not been examined experimentally, thus it is not possible to infer causality.

Regular breakfast eating is not only associated with enhanced nutritional profiles of young people, but also may be associated with greater physical activity levels. Lack of physical activity and increased sedentary behavior are risk factors for overweight and obesity during childhood and adolescence and can lead to developing chronic diseases, such as diabetes and cardiovascular disease (Lyerly et al., 2013). Current recommendations for daily moderate and vigorous physical activity are at least 60 minutes for children and adolescents aged 6-17 years (Lyerly et al., 2013, Shaefer et al., 2013), however previous studies have documented that a significant number of boys and girls did not meet the current guidelines for physical activity, adolescent girls in particular (Pearson et al., 2009). Indeed, boys have been found to be more physically active than girls (Cohen et al., 2003, Pearson et al., 2009, Vissers et al., 2013), and younger adolescents engage in more physical activity per day than older adolescents (Pearson et al., 2009). In addition, 83% of girls did not meet the recommendations for physical activity (Pearson et al., 2003) and 51% for breakfast consumption (Lyerly et al., 2013) in the UK. There is some evidence to suggest that breakfast consumption is associated with greater physical activity levels in young people (Corder et al., 2014), with others reporting no relationship (Lyerly et al., 2013). Although experimental studies examining the effect of breakfast consumption compared with omission on activity levels in young people are not available, a recent randomised-controlled trial in adults reported that breakfast consumption is causally linked with higher physical activity energy expenditure (Betts et al., 2014).

It is clear that the findings on breakfast consumption in relation to dietary intakes and physical activity remain equivocal. This may partly be due to various definitions of breakfast and methods used in previous literature. Diet and physical activity are perhaps most important modifiable risk factors for overweight and obesity (Frieden et al., 2010), but a lack of experimental evidence of the effects of breakfast on these factors in children and adolescents makes it impossible to infer causality. Only one experimental study by Kral et al. (2011) has examined the effects of breakfast on energy intake for the remainder of the day in children. However, the results were obtained on a single occasion under laboratory conditions, and the sample was limited to a normal-weight 8-10-year old children. Moreover, experimental evidence examining the effect of breakfast consumption on snack intakes, fruit and vegetable consumption, and physical activity does not appear to be available. It is also worrying that according to previous findings adolescent girls in particular appear to reduce their breakfast consumption with age (Timlin et al., 2008) and fail to meet the guidelines for physical activity for young people (Pearson et al., 2003). Therefore, the present study aims to examine the effect of breakfast consumption compared with breakfast omission on daily energy intake and physical activity in overweight and non-overweight adolescent girls.

Primary aims:

1) To examine the effects of consuming compared with omitting breakfast on daily energy intake in overweight and non-overweight adolescent girls
2) To examine the effects of consuming compared with omitting breakfast on daily physical activity in overweight and non-overweight adolescent girls

Secondary aims:

1) To examine the effects of consuming compared with omitting breakfast on daily high-fat and sugary snack consumption and fruit and vegetable consumption in overweight and non-overweight adolescent girls
2) To examine interactions with weight status (i.e. establish whether any effects of consuming compared with omitting breakfast differ between overweight and non-overweight girls)

3) To examine interactions with habitual breakfast consumption (i.e. establish whether any effects of consuming compared with omitting breakfast differs between habitual breakfast consumers and skippers)

2 Review of Literature

The purpose of this chapter is to review and to critically examine the literature investigating the relationships between and potential effects of breakfast consumption on weight status, dietary intake and physical activity in children and adolescents. The first section reviews the relationship between obesity, weight status and breakfast consumption among young people. This is followed by a closer look at the prevalence and definition of breakfast consumption in children and adolescents. The third section focuses on nutritional benefits of breakfast and investigates, in detail, epidemiological evidence on daily energy intakes, eating patterns and snacking, and how the type of the breakfast may affect dietary intakes. The next section discuses other benefits of breakfast, leading to an in-depth discussion of experimental evidence available on breakfast, diet and physical activity. The final section of this chapter provides a brief summary of the literature that has been reviewed.

2.1 Childhood obesity, energy balance and breakfast consumption

Overweight and obesity represents a major health concern and economic burden in children and adolescents (Reilly et al., 2006., Wang et al., 2011) and obesity rates in young people have reached epidemic levels (Toschke et al., 2008). According to the Health Survey for England (2013), approximately one third of boys and girls aged 2-15 years are classified as either overweight or obese, and the numbers of young obese young people in England are expected to grow. It is estimated that 30% of obesity begins in childhood, and about 50 to 80% of obese children become obese adults (Arora et al., 2012). Obesity and weight gain result from an imbalance between energy intake and energy expenditure and occur as a result of a sustained positive energy balance, which occurs when energy intake exceeds energy expenditure. Positive energy balance could be due to increased food intake, decreased energy expenditure, or a combination of the two (Troiano et al., 2000). Based on epidemiological data, trends in overweight prevalence indicate that many children are in positive energy balance (Mei et al., 1998).

Cross-sectional data suggests that children and adolescents who regularly skip breakfast have higher BMI’s (Deshmukh-Taskar et al., 2010, Dialektakou et al., 2008, Dubois et al., 2007, Keski-Rahkonen et al., 2003, Sjöberg et al., 2003) and higher waist circumference (Deshmukh-Taskar et al., 2010) than breakfast eaters, showing an increased BMI with the average difference of 0.78 kg/m² in those who skip the meal

(Szajewska and Ruszczynski, 2010). It has been demonstrated that there is an association between obesity and breakfast consumption in 10-16-year-old children suggesting that breakfast skippers are more likely to be obese than regular breakfast consumers (Sandercock et al., 2010), and that prevalence of overweight and obesity in adolescents aged 12-18 who consume breakfast regularly was lower than in those who sometimes and never ate breakfast (Arora et al., 2012). Girls who never ate breakfast were almost twice as likely to be obese compared with girls who always ate breakfast (Sandercock et al., 2010, Szajewska and Ruszczynski, 2010). Contrary to these results Sjöberg et al. (2003) found that BMI was not significantly higher in girls who skipped breakfast. Despite of similar results reported by many, but not all, cross-sectional studies, there are differences in breakfast skipping and consumption definitions and methodology which makes it challenging to interpret the outcomes (see section 2.3, 'Definitions of breakfast'). In addition not all studies controlled for confounding factors, such as physical activity, socio-economic status, parental education and number of parents, which can remarkably influence weight status (Deshmukh-Taskar et al., 2010, Sjöberg et al., 2003). Lastly, it is not possible to infer causality from these studies.

Longitudinal studies have demonstrated that frequency of breakfast consumption among children decreased with age, whereas BMI increased with age (Barton et al., 2005, Berkey et al., 2003, Timlin et al., 2008). Convincing data for the relationship between breakfast consumption and lowered BMI has come from a 5-year prospective analysis by Timlin et al. (2008), where both cross-sectional and prospective analyses revealed that the frequency of breakfast eating was inversely related with BMI in a strong dose-response manner in 14 and 19 year old adolescents. Interestingly, dieting and weight-control behaviors were inversely related to breakfast frequency, suggesting that skipping breakfast was used as an attempt to lose weight. This might suggest that it may not be regular breakfast consumption that can cause weight loss, but that obesity may actually cause breakfast skipping. The analysis controlled for several confounding factors such as race/ethnicity, age, socio-economic status, physical activity and dietary and weight-related variables (which did not explain the findings), however relied on a self-reported measurements for weight and height. Barton et al. (2005) has evaluated data from National Heart, Lung, and Blood Institute Growth and Heath Study and reported similar results to those of Timlin et al. (2008) regarding frequency of breakfast and changes in BMI. They examined changes in breakfast and cereal consumption in relation to BMI of girls aged 9 and 19 years. Cereal and 'other breakfast' female eaters had lower BMIs than girls who did not eat breakfast. They also suggested that girls who consumed cereal breakfast had lower risk of becoming overweight than girls who skipped breakfast; consistent cereal eating was predictive of lower BMI. Furthermore breakfast may confer several health benefits over the lifespan; children who skip breakfast were found to have larger waist circumference, higher fasting insulin, total cholesterol, and low-density lipoprotein (LDL) cholesterol in both childhood and adulthood (Smith et al., 2010) resulting in a higher risk of metabolic and cardiovascular disease, certain types of cancer, hypertension and type 2 diabetes (Toshke et al., 2008). Interestingly, there is also evidence to suggest that the relationship between breakfast consumption and BMI may depend on initial weight status; overweight breakfast skippers had reduced BMIs over time when compared with overweight breakfast consumers, whereas non-overweight skippers gained weight over time compared with normal weight breakfast consumers (Berkey et al., 2003, Timlin et al., 2008). These findings may suggest that daily breakfast consumption could be used as an initiative to prevent, rather than treat, obesity in young people.

In general, numerous cross-sectional and longitudinal studies have explored the relationship between regular breakfast eating and weight status across the world. Inverse relationships between breakfast consumption and BMI were reported in several studies among children and adolescents, suggesting that breakfast skippers have higher BMI than breakfast consumers and have greater risk for overweight and obesity (Berkey et al., 2003, Szajewska and Ruszczynski, 2010). However, this epidemiological data remains inconclusive, which may be attributed to various definitions of breakfast consumption and skipping, self-reported measurements, controlling/not controlling for possible confounding factors and dietary assessment methods used in cross-sectional and longitudinal studies. Furthermore, it is not known whether regular breakfast omission is causally linked with weight gain and obesity.

2.2 Prevalence and definition of breakfast

Many studies have documented a decline in breakfast consumption over past decades (Arora et al., 2012, Berkey et al., 2003, Timlin et al., 2007, Toschke et al., 2009) with about one third of young people in England now omitting breakfast regularly (Sandercock et al., 2010). Moreover numerous cross-sectional and longitudinal studies found that breakfast consumption decreases with age (Barton et al., 2005, Rampersaud et al., 2005, Sandercock et al., 2010, Timlin et al., 2008) and that breakfast skipping is particularly common in adolescent girls (Sjöberg et al., 2003, Timlin et al., 2008, Vissers et al., 2013) who may use it as a means to lose weight (Cohen et al., 2003, Timlin et al., 2008). Sandercock et al. (2010) reported that around 30% of 10-16-year old English schoolchildren and adolescents of which about 55% were girls, do not eat breakfast daily (on four or less than four days a week), with this prevalence rising with age. Common reasons given by children and adolescents for breakfast skipping include: lack of time, not feeling hungry in the morning, or would rather sleep (Keski-Rahkonen et al., 2003, Rampersaud et al., 2009).

It should be noted that different studies define breakfast and breakfast skipping in different ways, which makes it challenging to directly compare results between studies. Across the studies definitions of breakfast vary according to the foods consumed at breakfast, and day and time of the meal (Rampersaud et al., 2009). Some studies have defined breakfast as the first meal of the day consumed at home (Keski-Rahkonen et al., 2003) or as a meal eaten between 6.00-09.00 (Dubois et al. 2007) or 5.00-10.00 (Albertson et al. 2008), however the breakfast occasion was often self-defined by participants (Barton et al., 2005, Berkey et al.,. 2003, Timlin et al., 2008, Toschke et al., 2008). A self-administered questionnaire where breakfast skipping is defined as having or not having breakfast on the day of the survey is one of the methods used previously (Dialektakou et al., 2008); this may not represent habitual breakfast consumption as breakfast habits may vary on daily basis and on the weekend compared with a weekday, which can affect the outcomes of the studies conducted on a school day on a single occasion (Rampersaud et al., 2009). Other studies have assessed breakfast consumption on a frequency basis by asking participants: “On how many days do you/your child eat(s) breakfast?” (Arora et al., 2012, Berkey et al., 2003, Croezen et al., 2007, Dubois et al., 2009, Pearson et al., 2009, Sandercock et al., 2010, Sjöberg et al., 2003). Some studies have used more qualitative terms such as whether participants consumed breakfast ”never”, ”sometimes” or ”always” (Timlin et al., 2008, Keski-Rahkonen et al., 2008). Self-reported 24-hour dietary recall method and 3-day food records have also been employed to distinguish between breakfast consumers and skippers (Barton et al., 2005, Deshmukh-Taskar et al., 2010, Alberson et al., 2008).

Moreover, Dialektakou and et al. (2008), who compared associations between BMI and breakfast skipping for 24 definitions of breakfast skipping, have found that a relationship between BMI and breakfast skipping was dependent on how breakfast skipping was defined. The percentages of breakfast skippers in this study varied with the definition of breakfast skipping from 3.6% to 74.7%. Breakfast skipping on the day of the data collection was significantly associated with BMI. On the other hand, there were few significant associations with BMI when breakfast consumption was defined on a frequency basis consumed by participants during previous week. There was a significant relationship among BMI and breakfast consumption 0 to 2 times a week, but no relationship when breakfast was consumed 0, 0 to 1, 0 to 3 and 0 to 4 times per week. The authors suggested that such discrepancy in findings could be attributed to recall errors. As well as highlighting difficulties when making between-study comparisons, these findings also highlight the importance of employing a standardised method to define ‘breakfast’ in future observational and experimental research.

2.3 Energy intake and energy expenditure assessment

2.3.1 Dietary intake assessment

Food intake in children and young people has been evaluated by a variety of methods, including the 24-hour recall, food frequency questionnaires and food records, in previous studies investigating the associations between breakfast and health. The 24-hour recall involves recording food intake in the last 24 hours; considering that memory of recent food intake within the past 24 hours may be more precise than leaving longer time periods, the quantities of the foods may be estimated more accurately (Block, 1982). In a food frequency questionnaire, a participant reports the frequency of consumption and portion size of specified items over defined period of time (Block, 1982). It can be administered quickly and thus is often used in large-scale epidemiological research (Block, 1982). Nevertheless, both food frequency questionnaires and the 24 h dietary recall may not represent appropriately participants' typical dietary behaviours (Lyerly et al., 2013) and reflect food and nutrient intake on weekend given that recalls are typically obtained on a school day (e.g. Nicklas et al., 2000). Boushey et al. (2009) suggested that older (15 to 18-year-old) children are more likely to underreport than younger (7-12-year-old) children due to greater food intakes, unstructured eating habits and eating out more frequently. This makes the 24 hour recall and food frequency questionnaires difficult to undertake. Food records are similar to 24-hour recall, except that food intake is recorded over several days (for example 3, 4, or 7 days) and involves weighing, measuring or estimation of portion size (Block, 1982). Food diaries exhibit better representation of participants' habitual diet as data is typically collected over at least three days. A study by Crawford et al. (1994) demonstrated that 3-day food record was in a better agreement between observed and reported food intake compared with the 24-hour recall and 5-day food frequency and produced least recall errors in 9-10-year-old girls. Moreover, food records over a 3-day period has been shown to provide with more accurate information on food intake than food records over longer periods (>4 days) due to participant fatigue (Thompson and Byers, 1994). However, dietary recalls rely on memory (Nicklas et al., 2012) and for ease of completion of food records, participants may alter their usual dietary intakes and eat and record certain foods (Vissers et al., 2013). Weighed food records have been found to give the most accurate results when estimating energy intake and highly correlate with biological markers, such as urine samples, of food intake (Bingham et al., 1997). This gold-standard method requires that all foods and leftovers are recorded during each meal (Small et al., 2009). However, it has been reported that weighed dietary records impose a great burden on participants due to impracticality of the method leading to underestimation of energy intake in adolescents, particularly in overweight and obese (Livingstone et al., 1992), whereas the diet history gives better estimates of food intake (Burrows et al., 2010). Use of technology, including digital photography, in children's dietary assessment has been shown to increase validity and feasibility in measuring food intake and food leftovers in daycare and as well as home settings (Nicklas et al, 2012). Digital photography has also been demonstrated to improve estimation of portion size in children (Martin et al., 2007). Moreover, Boushey et al. (2009) reported that adolescents preferred using digital devices to traditional methods when assessing dietary intake, engaging them in the activity of keeping dietary intake diary. Therefore, incorporating digital device (e.g. photography) in the dietary assessment of young people may prove valuable in improving the poor compliance seen with weight food diaries. Nevertheless, collecting accurate and reliable food intake information in young people remains challenging (Nicklas et al., 2012).

2.3.2 Physical activity assessment

Various methods have been used to measure physical activity in children and adolescents in previous breakfast-related research. Currently available methods have strengths and limitations with regard to accuracy, cost, practicality, and degree of invasiveness. The outcomes of most studies (Arora et al., 2012, Cohen et al., 2003, Sandercock et al., 2010, Timlin et al., 2008) examining the relationships between breakfast and physical activity are based on self-reported physical activity questionnaires, consisting of structured questions that provide information on the time spent performing various activities in different intensities and frequency of activities (Craig et al., 2003). Although such questionnaires are an inexpensive measurement of physical activity with low researcher and participant burden, the results derived from such questionnaires may be affected by recall errors, deliberate misrepresentation and social desirability (Sirard et al., 2001). Further, when validated against objective physical activity measurements such as heart rate monitors, pedometry and accelerometry, self-reported physical activity questionnaires demonstrated weak to moderate correlations in the majority of studies (Sirard, et al., 2001).

Doubly labelled water is used to assess energy expenditure in free-living conditions and is considered the gold standard technique. Doubly labelled water involves the ingestion of a quantity of water labelled with a known concentration stable isotopes of hydrogen and oxygen. As energy is expended in the body, carbon dioxide and water are produced, and the differences between the isotope elimination rates are used to calculate total energy expenditure (Sirard et al., 2001). Although this method provides accurate evaluation of energy expenditure, it is expensive and cannot be used in large case studies. Also, it only measures total energy expenditure, thus daily or hourly patters of physical activity cannot be examined (Sirard et al., 2001). Ardvidsson et al.

(2005) examined the validity of the physical activity questionnaire for adolescents against doubly labelled water, and found a large underestimation of energy expenditure due to unreported time spent in different activities. It is noteworthy that doubly labelled water can only assess total energy expenditure rather than structured physical and sitting activities. However, this can indicate that spontaneous nature of children and adolescents contributed to difficulties to recall all physical and sitting activities, especially unstructured activities or activities than are difficult to report such as various home activities or activities that are automatically done (Arvidsson et al., 2005).

Heart rate monitors and pedometers have also been employed to assess physical activity in children and adolescents. Pedometers are used to estimate the number of steps walked and some studies in adults have shown favourable validity and reliability of the device. However, they can only detect steps thus cannot assess patterns or intensity of activities (Sirard et al., 2001). In turn, heart rate monitors that can distinguish between heart rate that is affected by other factors (emotions, caffeine, medicines etc.) than movement and heart rate changes that result from physical activity have been demonstrated to provide information on both total energy expenditure and patterns of physical activity but the method relies heavily on individual calibration (Sirard et al., 2001).

Accelerometers measure accelerations produced by body movement and provide an objective assessment of physical activity, enables a more detailed examination of physical activity levels (sedentary, light, moderate, vigorous) and behaviours (morning, afternoon, evening physical activity) than pedometers and subjective self-reported physical activity questionnaires (Sirard et al., 2001). Hip- and wrist-worn accelerometers have been widely used in studies assessing physical activity in young people and shown to have high reliability and validity (Esliger et al., 2011). It has also been suggested that wrist-worn accelerometers may lead to greater compliance than hip-worn accelerometers when assessing habitual physical activity in young people. Hip-worn accelerometers are necessary to remove when changing clothes, sleeping, swimming, showering etc. whereas convenient body location and the ability to resist water of wrist-worn accelerometer can reduce the need to remove the monitor for these purposes (Phillips et al., 2013). However, accelerometers have limited ability to evaluate activities with limited torso movement, locomotion on a gradient and increased physical activity as a result of wrist movement (for instance when playing console games) (Phillips et al., 2013).

2.4 Associations between breakfast consumption and dietary intakes

2.4.1 Daily energy, macronutrient and micronutrient intakes

Observational data suggest that breakfast eaters have greater energy intakes, whereas both normal weight and overweight breakfast skippers have demonstrated lower energy intake than those who ate breakfast daily (Timlin et al., 2008). Sjöberg et al., (2003) reported that breakfast eaters had 6 to 7% higher energy intake compared with breakfast skippers. The fact that young breakfast eaters have been found to have greater total daily energy intakes has been supported by majority of the studies (Barton et al., 2005, Berkey et al., 2003, Deshmukh-Taskar et al., 2010, Nicklas et al., 2010). However, it has been suggested that overweight participants might underreport their energy, which results in lower daily intake of energy (Astbury et al., 2011). Furthermore, Dubois et al. (2008) found that breakfast skippers had similar energy intake compared with breakfast consumers in pre-school children. The authors suggested that pre-school children who missed energy intake from skipping breakfast compensated it through foods later in the day.

Breakfast has been demonstrated to make a valuable contribution to the nutritional diet quality of young people (Nicklas et al., 2000). Skipping breakfast has been found to often be linked to poorer nutritional habits and excess intakes of fat, saturated fat, cholesterol and sodium as well as lower than recommended intakes of calcium, zinc, iron, magnesium, copper, folate, vitamins A, B6, B1, C and E (Dubois et al., 2007, Nicklas et al., 2000). The dietary inadequacies occurred to be more prevalent in females than males (Nicklas et al., 2000), showing lower protein, calcium, fibre and zinc, and iron and vitamin C intakes in girls (Dubois et al., 2008, Sjöberg et al., 2003). In earlier studies, breakfast skippers had a lower percentage of energy from carbohydrates, total protein, fiber intake, vegetable protein, lactose and fructose that those who ate breakfast regularly (Dubois et al., 2008, Nicklas et al., 2000, Rampesaud et al., 2005), but higher percentage of energy intake coming from fats than breakfast consumers (Nicklas et al., 2000).

Dubois et al. (2008) reported that breakfast skippers consumed lower amount of protein, carbohydrate and fat than regular breakfast eaters if they had breakfast. Breakfast skippers consumed less protein on daily basis, more carbohydrates at afternoon and evening snacks, less fat during meals (lunch and dinner) but more fat from morning, afternoon and evening snacks than did breakfast consumers. Overall, breakfast skippers had a lower diet quality compared with breakfast consumers. The authors also found that breakfast skipping and grain products both were associated with overweight. Intake of energy, carbohydrates and grain products (which were consumed mostly at the dinner meal) were positively associated with mean BMI: the higher the energy intake, carbohydrate and grain products intakes the higher the BMI was in breakfast skippers, but not in breakfast eaters.

Furthermore, Nicklas et al. (2000) examined breakfast consumption with and without vitamin-mineral supplement in 15-year olds and found, that regardless of supplement use, breakfast eating made a significant contribution to total nutrient intake. Adolescents who missed breakfast or consumed an inadequate breakfast rarely made up the dietary shortages at other meals, and those who omitted breakfast also had lower total daily intakes of all vitamins and minerals, and were most likely to fail Recommended Daily Allowance (RDA) for all vitamins and minerals. A review by Rampersaud et al. (2005) revealed that breakfast eaters had higher daily intakes of micronutrients and were more likely to meet nutrient intake recommendations compared with breakfast skippers.

Breakfast eating has also been found to be associated with fruit and vegetable, grain and dairy products consumption. Dubois et al. (2008) found that pre-school breakfast skippers consumed a smaller number of servings from vegetables, grain products and milk products, with breakfast consumers having more servings of vegetables, grain and milk products throughout the day. Similarly Arora et al. (2012) reported that breakfast eaters were more likely to consume dairy products, fruits and vegetables, and Utter et al. (2007) reported that children aged 5-14 years who missed breakfast were less likely to meet recommendations for fruit and vegetable consumption. Contrary to that, Vissers et al. (2014) found no association between breakfast and fruit and vegetable consumption in 9 to 10 year old children, and unlike other studies in which dietary intake was assessed using 24h recall (Dubois et al., 2007) or food frequency questionnaire (Arora et al., 2012, Pearson et al., 2009), dietary intake in their research was assessed using 4-day food diary including weekdays and weekends. Discrepancies between studies might be partially explained by the age of the participants; Pearson et al. (2009) found in cross-sectional survey in 12 to 16-year olds that older adolescents consume more servings of fruits and vegetables than younger adolescents, and were more likely to meet recommendations.

Despite evidence that breakfast consumers demonstrated greater energy intakes and better nutritional profiles than breakfast skippers in many studies, the results still remain equivocal. Differences between the studies can be partially explained by various methods used to estimate energy and nutrient intakes.

2.4.2 Eating patterns and snacking

Breakfast skipping has been found to be associated with greater consumption of unhealthy snack food, such as sweets, baked goods and soft drinks (Utter et al., 2007), and fewer consumption of other meals (Sjöberg et al., 2003) than breakfast eating, which may lead to weight gain (Keski-Rahkonen et al., 2003). Indeed, Sjöberg et al. (2003) who explored food habits in 15 to 16-year-olds, reported that irregular breakfast eaters consume greater energy from snacks and a higher per cent of energy from in-between meals and snacks. They also reported that irregular breakfast eating was related to omitting lunch or dinner. Similarly, Dubois et al. (2008) found that breakfast skippers had higher energy intakes at the evening snacks than those who ate breakfast daily in pre-school children. In this study, meals were grouped into two time periods: food and beverages consumed between 06.00-13.00 including breakfast, brunch, morning snacks and lunch, and foods and beverages consumed after 13.00 including afternoon snacks, dinner and evening snacks. Therefore, meal patterns at different times of the day were explored and the results revealed that breakfast skippers consumed less energy at breakfast (on the few days that they consumed breakfast), but more energy at lunch and during afternoon and evening snacks. Their intake of carbohydrate at breakfast and in their morning snack was less than that of breakfast eaters, but more at afternoon and evening snacks and at dinner. Overall, these finding suggest that breakfast omission may lead to higher energy and carbohydrate intakes later in the day, particularly in the form of snacks. There is also some research that has examined the relationship between meal frequency, breakfast consumption and childhood obesity in 5 to 6 year old children, with findings suggesting that breakfast did not contribute to the inverse relationship between higher meal frequency and childhood obesity (Toschke et al., 2009). Studies in older children and adolescents reported similar results indicating that higher meal frequency is associated with lower body weight status (Antonogeorgos et al., 2012, Franko et al., 2008, Mota et al., 2008). Moreover, in a ten-year longitudinal observational study, Franko et al. (2012) found that meal frequency decreased with age among 9-19-year-old girls. Antonogeorgos et al. (2012) reported that 10-12 year olds who consumed more than 3 meals a day were two times less likely to be overweight or obese than those who ate less than 3 meals per day. Importantly, in this study this was only true if-and-only-if breakfast was consumed daily.

2.4.3 Effect of the type of breakfast

Although breakfast eaters have demonstrated a more positive and favorable dietary profiles, it has been suggested that it may be not breakfast consumption *per se* that contributes to such positive health outcomes, but specific foods consumed at a time of the meal (Barton et al., 2005). Several studies have reported particularly positive associations between breakfasts that include ready-to-eat cereal (RTEC) and nutrient intakes. Consumption of RTEC was found to be related to higher intakes of fibre, calcium, iron, folic acid, vitamin C and zinc, and lower intake of fat and cholesterol compared with breakfast classified as 'other breakfasts' (Barton et al., 2005). Deshmukh-Taskar et al. (2010) have also reported that, regardless of concerns that RTEC can contribute to added sugar in the diet, which may cause weight gain if consumed in high amounts (>25% of total energy intake), breakfast skippers had higher intake of added sugar than breakfast eaters (cereal and other breakfast eaters), supposedly at other meals and snacks. Importantly, intake of added sugar in breakfast eaters did not exceed recommendations. Therefore, cereal consumption as a part of a healthy lifestyle may play a significant role in meeting recommended nutrient intake.

It is noteworthy that the nutritional content of RTEC can differ substantially, and the majority of cereal available on the market fails to meet nutritional recommendations. Cereals marked specifically to children typically contain high glycemic index (HGI) carbohydrates, are more energy-dense, and contain more sugar and salt, but less fibre and protein than cereal not specifically marked to children (Schwartz et al., 2008). Glycemic Index (GI) relates to the rate at which the carbohydrates are absorbed after a meal (Jenkins et al., 1981). In contrast to HGI breakfasts, cereal breakfasts with low glycemic index (LGI) carbohydrates contain a lower energy density and have greater amounts of dietary fibre (Tolfrey and Zakrzewski 2012). There is evidence to suggest that LGI breakfasts result in relatively lower postprandial blood glucose levels (Tolfrey and Zakrzewski 2012), can increase satiety (Warren et al. 2003) and be used as a means of weight control and obesity management in young people (Fajcsak et al., 2008, Rovner et al., 2009). High-fibre breakfasts have similar effects on blood glucose levels and satiety (Slavin and Green, 2006) with some evidence suggesting that adolescents with low fibre intake are more likely to be overweight compared with those with higher fibre intake and that increased fibre intake promotes weight loss (Anderson et al., 2009).

Dietary fibre is important in childhood as it may contribute significantly to health benefits such as maintenance of normal blood glucose and lipid levels and blood pressure as well as promotion of normal gastrointestinal function thus reducing the risk of cardiovascular disease and type 2 diabetes (Anderson et al., 2009). High-fibre foods have lower energy density compared with foods such as high-fat foods (Slavin and Green, 2006). It has been suggested that the physical and chemical properties of fibre promote early signals of satiation and increase or prolong satiety (Burton-Freemen, 2000). Satiety signals occur in both pre- and post- absorptive phase. Viscous soluble fibre may prolong the intestinal phase of nutrient digestion and absorption allowing longer time for macronutrient interaction in the pre-absorptive phase as well delay post absorptive signals (Slavin and Green, 2006). Further, decreased gastric emptying and slower nutrient absorption leads to lower postprandial glucose and lipid levels (Slavin and Green, 2006). Indeed, experimental data have demonstrated that fibre rich foods affect appetite by increased feelings of satiation and satiety (Pereira et al., 2010). In addition, dietary fibre was reported to have only a little effect on blood glucose (Jenkins, 1981), moreover, fibre-rich breakfast may improve blood sugar control and possibly hinder decrease in blood glucose levels between meals (Liljeberg et al., 1999).

The effects of HGI and LGI meals on blood glucose, insulin and satiety have been extensively examined in adults suggesting that LGI foods can be used in prevention of obesity, diabetes and cardiovascular disease (Brand-Miller et al., 2009) with relatively a small number of experimental evidence on the impact of GI available in children and adolescents. One of the few studies investigating GI effects in young people and determining the concentrations of blood glucose and insulin by Ludwig et al. (1999) reported that voluntary energy intake and hunger ratings were highest after HGI, followed by moderate GI (MGI) and lowest after consuming a LGI breakfast in obese teenage boys. Moreover, compared with HGI meal, LGI breakfast resulted in reduction of plasma glucose and serum insulin levels. These results are consistent with Ball et al. (2003) in adolescent boys and girls. In another study, greater glycaemic response to HGI compared with LGI was documented more in overweight compared with non-overweight girls (Zakrzewski et al., 2012). Other studies examining the effects of LGI breakfast on satiety and food intake reported equivocal results. Warren et al. (2003) found higher hunger ratings prior lunch time following HGI breakfast compared with LGI breakfast in preschool children; pre-lunch satiety ratings were inversely associated with food intake at lunch, whereas similarly to Warren et al. (2003) findings concerning hunger ratings prior lunch, LaCombe and Ganji (2010) reported that 4-6-year old children did not consume more energy during lunch after consuming LGI or HGI breakfast. In support, although found a tendency in reduced energy intake at lunch following LGI breakfast compared with HGI breakfast among boys, Henry et al. (2007) reported no significant food intake during lunch between two conditions. Additionally, not all the studies documented an effect of breakfast GI on satiety in children and adolescents (Pereira et al., 2010, Zakrzewski et al., 2012).

The increased hunger ratings following HGI breakfast compared with LGI breakfast may be a result of LGI meal on hormonal and metabolic consequences (LaCombe and Ganji, 2010). A rapid rise in blood glucose following consumption of HGI food occurs as HGI foods are more readily digestible and leads to large insulin response inhibiting glucagon, a hormone involved in glycogen synthesis and regulated by blood glucose concentration release (Ball et al., 2003, Ludwig et al., 2002). Large insulin responses increases glucose uptake by muscle and liver. At the same time lipolysis and release of glucose from the liver into the circulation are suppressed (Radulian et al., 2009). These reactions result in rapid reduction of concentration of blood glucose after consuming a HGI food compared with a LGI food. Therefore, the hunger response occurs earlier after eating a HGI meal compared with a LGI meal (Ludwig et al., 1999). As a consequence the perceived hunger sensation may initiate subsequent meal and result in increased energy consumption at a subsequent meal (LaCombe and Ganji, 2010). Conversely, LGI breakfast consumption induces more subtle hormonal responses and the prolonged and continuing nutrient absorption postpones hunger response by promoting longer satiety (Ludwig et al., 1999).

It should be noted that the discrepancies in the hunger response among young people may be due to different postprandial periods used in previous studies, for instance 2-h (Zakrzewski et al., 2012) vs. 3-4-h (Buyken et al., 2007) period suggesting that shorter postprandial periods may not indicate differences in satiety. More importantly, some studies did not match macronutrient composition (LaCombe and Ganji, 2010) and fibre content (Warren et al., 2003) of breakfast which along with cooking method, processing and coingested food influence GI of a food (Ball et al., 2003). Protein and fat were found to reduce the glyceamic response (Jenkins et al., 1981) and trigger the release of cholecystokinin (CCK) hormone which as a result leads to decreased gastric emptying (deGraaf et al., 2004). This further leads to prolonged satiety (LaCombe and Ganji, 2010). Moreover, Anderson and Woodend (2003) suggested that carbohydrate component is not the only characteristic of GI of a food as in previous studies protein was found to be more satiating than fat and carbohydrate with diets containing more protein leading to greater satiety and weight loss in obese adults.

In addition, the GI of a food is only one characteristic of carbohydrates that signals satiety (Buyken et al., 2007). Macronutrients also affect stimulation of number hormones released into the bloodstream that regulate appetite (deGraaf et al., 2004). For instance, glucagon-like peptide 1 (GLP-1) is produced in response to presence of carbohydrate and fat and stimulates cells in pancreas to secrete insulin, thus decreasing blood glucose concentrations in response to carbohydrate ingestion (Silva and Bloom, 2012). GLP-1 is suggested to affect appetite by promoting moderate and stable flow of nutrients from the stomach to the small intestine (deGraaf et al., 2004). Peptide YY (PYY) was reported to signal achievement and maintenance of satiety following food ingestion; however data on PYY is limited (Brownley et al., 2010). Studies showed that hormone PYY is released after food ingestion and is particularly stimulated by high-fat foods, whereas protein was shown to delay release of PYY (deGraaf et al., 2004). The initial release of PYY is suggested to be under neural control and its effect on appetite via direct central effect (signal on central nervous system) (Silva and Bloom, 2012). Both, GLP-1 and PYY are considered to suppress appetite

(Parnell and Reiner, 2009). Another hormone, which was found to be an excellent biomarker of satiety, is ghrelin as there appears to be a close correspondence between appetite and ghrelin concentrations (deGraaf et al., 2004). Ghrelin acts as a peripheral hormone on receptors in the hypothalamus and is synthesised in human stomach and gastrointestinal tract and increases appetite and stimulates the release of growth hormone (Fry and Ferguson, 2009). Ghrelin concentrations are elevated prior a meal and decrease quickly after the meal is consumed (deGraaf et al., 2004). In turn, dietary fibre has been found to lower ghrelin concentrations and increase secretion of GLP-1 and PYY (Weickert and Pfeiffer, 2008), therefore suggesting that wholegrain, fibre-rich breakfast may result in reduced energy intake.

2.5 Other benefits of breakfast consumption

In addition to contributing to whole-diet nutrient adequacy, regular breakfast consumption can enhance cognitive and academic performance in children (Barton et al., 2005, Rampersaud et al., 2005, Tolfrey and Zakrzewski 2012, Szajewska and Ruszczynskia 2010) by alleviating hunger that has been associated with emotional, behavioral, and academic problems in children and adolescents; however several experimental studies do not support these findings (Rampersaud et al., 2005). The experimental studies that support the evidence of positive effects of breakfast have reported beneficial effects of breakfast on memory function, episoidic memory, and both short-term and long-term memory. Outcomes of some experimental studies and observational studies have also reported improved school attendance and improved academic and achievement test scores as a result of regular breakfast consumption (Rampersaud et al., 2005). Breakfast skipping has also been associated with decrease in attention level (Lyerly et al., 2013).

It is also of concern that irregular breakfast eating in adolescents has been found to be related to higher intake of sucrose and alcohol (Keski-Rahkonen et al., 2003, Sjöberg et al., 2003), and use more coffee and caffeinated sodas (Keski-Rahkonen et al., 2003), as well as smoking (Croezen et al., 2009, Keski-Rahkonen et al., 2003, Sjöberg et al., 2003).

2.6 Breakfast consumption and physical activity

Several epidemiological studies have investigated the relationship between breakfast consumption and physical activity levels in young people. It has been mentioned previously that there is some evidence that habitual breakfast consumers have greater daily energy intakes than breakfast skippers; this suggests that breakfast consumers may have greater energy expenditures to maintain a lower BMI (Sandercock et al.,

2010) and energy balance (Troiano et al., 2000) than breakfast skippers. Indeed, there is some evidence that breakfast eaters have higher levels of physical activity than those who omit breakfast (Timlin et al., 2008).

Sandercock et al. (2010) and Timlin et al. (2008) reported higher physical activity levels in children and adolescents aged 10 to 16 years and 14 to 19 years, respectively, who regularly eat breakfast. Arora et al. (2012) found higher levels of physical activity of mild, moderate and strenuous intensities among breakfast eaters. However, Arora et al. (2012) found no differences in sedentary behavior such as watching TV, playing video/computer games. Greater physical activity has also been documented to be related to cereal consumption specifically (Albertson et al., 2008, Barton et al., 2005, Deshmukh-Taskar et al., 2010, Rampersaud et al., 2005, Timlin et al., 2008).

More recently, studies using objective measures of physical activity have, however, produced mixed findings on associations between breakfast consumption and physical activity in young people. Corder et al. (2011) found that girls, but not boys, who were occasional breakfast eaters demonstrated lower physical activity during the morning (6.00-12.00) compared with regular breakfast eaters in 14 year old adolescents. Vissers et al. (2013) investigated the relationship between moderate-to-vigorous physical activity (MVPA) and breakfast consumption in 9 to 10 year old children and discovered an association in boys, but not girls, with boys who consumed breakfast having higher MVPA on weekday afternoons and evenings, and weekend mornings, and spending less time sedentary during the morning than breakfast skippers. Another study by Corder et al. (2014) reported that breakfast consumption was associated with higher MVPA on weekends but not weekdays. They also reported increased physical activity in boys and girls who regularly consumed breakfast, particularly in the morning. In this study the authors also displayed hourly patterns (06.00-00.00) of MVPA by breakfast status (regular/irregular breakfast consumer) and conducted within-subject comparisons for each participant. Of particular interest is the finding that inconsistent breakfast consumers performed more MVPA on days when they consumed breakfast, which may suggest that breakfast eating could cause higher physical activity levels in adolescents. However, other studies have failed to support the relationship between breakfast consumption and physical activity. For example, Lyerly et al. (2013) and Utter et al. (2007) found no association between breakfast skipping and meeting physical activity guidelines among 12 to 19-year and 5 to 14-year old children and adolescents respectively.

The discussed studies examining breakfast consumption and physical activity levels and behaviours demonstrate inconsistent and limited results; some studies have found that breakfast skippers have lower physical activity levels (Arora et al., 2012, Sandercock et al., 2010, Timlin et al., 2008), other studies found lower physical activity in breakfast skipping in certain subgroups (e.g. boys but not girls) (Vissers et al., 2013), and some studies have found no relationship between breakfast consumption and physical activity (Lyerly et al., 2013). The inconsistency in results may be attributed to differences in methodology (e.g. assessment of physical activity and definition of 'breakfast'), sample size and age range, and possible confounding factors such as parental education level and socio-economic status. The outcomes of most studies (Arora et al., 2012, Cohen et al., 2003, Sandercock et al., 2010, Timlin et al., 2008) are based on self-reported physical activity questionnaire which are prone to bias. Moreover, some studies used self-reported physical activity questionnaire defining physical activity levels as mild, moderate and strenuous (Timlin et al., 2008), and some studies used self-reported minutes of physical activity in accordance with national guidelines for physical activity (Lyerly et al., 2013).

Although accelerometry provides an objective assessment of physical activity, different monitors (heart rate and movement sensor used by Corder et al. 2014 and waist-worn monitor used by Pearson et al., 2009, Vissers et al., 2013) were used in the studies, as well as different periods of measurement (4 vs. 7 days), and data was recorded in different intervals (5 vs. 30 sec epochs) which may impact the differences in the results. In addition, waist-worn accelerometers require the removal of the monitor when, for example, sleeping, swimming, or non-compliance may arise from children removing monitors by choice (Phillps et al., 2013).

Additional factors that may explain discrepancies in findings include the sample size (these vary from 170 to 4300 young people) and age ranges of the participants (from 8 to 19 years). Indeed, younger children have been shown to engage in more physical activity than older children and adolescents (Pearson et al., 2009). Importantly, because of the nature of the studies, it is not possible to infer causality and experimental research on the effect of breakfast on physical activity in young people does not appear to be available.

2.7 Experimental evidence: breakfast, diet and physical activity

Cross-sectional and longitudinal studies on breakfast among children and adolescents have demonstrated an association between breakfast and health related benefits (e.g. lower risk of obesity, favourable nutrient intakes and higher physical activity). However, because of the nature of the studies it is not possible to directly infer cause-and-effect relationships. These studies fail to answer the question whether skipping breakfast directly causes poorer diet quality, lower physical activity and obesity in young people. Although it has often been assumed that skipping breakfast can cause obesity, the finding that adolescents cite 'weight loss' as a reason to skip breakfast suggests that obesity may actually predispose breakfast skipping (Timlin et al., 2008).

In young people, there seems to be only one study available which has investigated the effects of breakfast on subsequent energy intake experimentally. Kral et al. (2011) compared breakfast consumption with omitting breakfast on subsequent ratings of hunger and energy intake in 8 to 10-year old children. A sample of 21 children underwent two interventions on two different occasions. The participants either consumed a compulsory cereal breakfast of their choice (all three options had energy content of 130 kcal), milk, banana and orange juice (amounting to 350 kcal in total) or no breakfast at the research laboratory. Children were also served lunch, where they could eat as much or as little as they desired. They also rated their appetite through the morning, and parents kept their child's food diary for the remainder of the day. Despite higher subjective ratings of hunger throughout the morning and higher ratings of prospective consumption before lunch during the breakfast omission condition, energy intake consumed at lunch or for the remainder of the day was not different between the two conditions. Consequently, when total energy consumed at breakfast, lunch, dinner and snacks for the day was examined, results revealed that total daily energy intake was higher during the breakfast consumption compared with omission condition. A potential limitation of this study was that the results of the study are based on a single occasion tested in laboratory setting. Indeed, it is possible that any effects of omitting breakfast on energy intake may take longer than one day to occur and evaluation of dietary intake on a single day is not a valid representation of habitual diet (Martin et al., 2007). Moreover, it is possible that a larger breakfast with higher energy content may be more likely to produce reduced energy intake later in the day. Therefore, future research with larger breakfasts would be valuable.

Although only one study has experimentally examined the effects of breakfast on diet in young people, a number of studies in adults exist. Levitsky and Paconowski (2013) have reported similar results to that of Kral et al. (2011) in males and in females aged 18 to 23 years, where they compared the effects of omitting breakfast, consumption of a 350 kcal high-carbohydrate breakfast, and consumption of a 350 kcal high-fibre breakfast on energy intake at lunch. The participants rated their appetite through the day and were served lunch from a buffet table, and were instructed to eat as much or less as they wished. Although the hunger ratings before lunch were significantly higher on the breakfast omission occasion, energy intake was similar across conditions. Nevertheless, a second study in which breakfast was not limited and increased to 624 kcal, showed that missing breakfast resulted in increased energy intake at lunch, but not during other meals or energy intake from snacks. This suggests that a relatively high-energy breakfast may reduce energy intake at lunch in adults. Martin et al. (2000)

examined short-term metabolic and energy expenditure responses to breakfast and found that energy intake during other meals (lunch and dinner) in young men (mean age 28 years) who consumed a low-energy breakfast (~100kcal) for a period of two weeks was significantly higher than energy intakes of men on free-diet or high-energy breakfast (~700kcal) conditions. Men on the low-energy breakfast condition also reported greater ratings of hunger through the morning. Energy expenditure was higher after high-energy breakfast compared with low-energy breakfast but only during the morning. Interestingly, after consuming a high-energy breakfast there were differences in substrate oxidation: oxidation of carbohydrate was higher throughout the tested periods, but fat oxidation was lower, and remained same in spite of the ingestion of lunch consisting 30% of fat provided at the laboratory compared with low-energy breakfast, thereby suggesting that high-energy breakfast high in carbohydrate inhibits fat oxidation promoting temporary storage of fat. Astbury et al. (2011) has also reported increased energy intake in males (mean age 23 years) at the time of the test meal (lunch) after consuming a liquid preload under a breakfast omission condition compared with a breakfast consumption condition. Participants also experienced lower fullness and higher hunger ratings in the no breakfast condition compared with breakfast condition. Hormones GLP-1 and PYY responses were higher after the preload in the breakfast condition compared with fasting. An increase in GLP-1 and PYY in the breakfast condition may be related with reduced subjective appetite and energy intake. These hormonal changes may also explain the findings in increased hunger ratings throughout the morning when breakfast was omitted reported by Martin et al. (2000) and Kral et al. (2010).

When examining free-living energy intake and energy expenditure, Halsey et al. (2011) reported no difference in energy intake or energy expenditure (assessed using accelerometry) for both males and females when they consumed or skipped breakfast for one week. However, some effects emerged when they distinguished between habitual vs. irregular breakfast eaters; females who were habitual breakfast consumers, when under no breakfast condition, consumed more energy and ate more later in the day. A recent six week randomised-controlled trial reported no difference in daily energy intake between six weeks of breakfast consumption and fasting (fast until midday) in a sample of 21 to 60 year old adults (Betts et al., 2014). This study was the first and only long-term breakfast intervention as yet which shed light on physiological adaptation to sustained six week exposure to breakfast or its absence under free-living conditions. In addition to similar energy intake in both treatment groups, the authors found no change in resting metabolic rate, body mass and adiposity, no difference in dietary macronutrient composition, but, importantly, more stable afternoon and evening blood glucose levels in the breakfast group than in the fasting group. However, appetite-controlling hormones such as ghrelin, PYY and CLP-1 that are involved in regulation of appetite and energy balance did not differ between breakfast and fasting groups after six weeks of intervention. The study clearly showed that daily morning breakfast skipping did not cause weight gain in healthy lean adults, contradicting some of the epidemiological evidence that demonstrated positive association between breakfast skipping and weight status. It is noteworthy that breakfast was not standardized in this study; participants were required to consume breakfast consisting of ≥700 kcal before 11:00, but the quality of breakfast was not specified which may explain similar energy intake between breakfast and fasting conditions. The main finding of this study, however, related to physical activity energy expenditure. Interestingly, Betts et al. (2014) documented higher light intensity activities performed in the morning during a six-week breakfast condition compared with no breakfast condition using in-depth laboratory tests, which resulted in greater daily energy expenditures in those who received the breakfast intervention. Importantly, these effects of breakfast were equally apparent on the first and final week of the intervention, suggesting an immediate effect of consuming breakfast on daily energy expenditure.

It has been proposed that skipping breakfast or poor quality breakfast may result in low energy levels and thus reducing physical activity in young people especially in the morning (Vissers et al., 2013) whereas energy and nutrient obtained from breakfast allow for better physical activity performance (Lyerly et al., 2012). Children aged 10 demonstrated a significantly better physical activity endurance test performance before lunch after consuming a larger breakfast (approximately 20% of their estimated daily energy requirements) compared with those who consumed breakfast comprising only 10% of the requirement (Wyon et al., 1997). Furthermore, inadequate breakfast was reported to fail to meet energy expenditure requirements of adolescents participating in physical activity in the morning (Vermorel et al., 2002). Additionally, it has been suggested that low physical activity levels as a consequence of breakfast skipping may be attributable to reduced glucose availability (Betts et al., 2014). The possible mechanism for increased energy expenditure in the morning following breakfast consumption may be that an influx in blood glucose signals the transition from the fasted to fed state and thereby enabling greater light physical activity energy expenditure levels. Conversely, the transition may be delayed as a result of skipping breakfast, due to lack of glucose available imposing limit on energy expenditure via physical activities (Betts et al., 2014).

Unfortunately, experimental evidence on breakfast consumption and physical activity in children and adolescents does not appear to be available. Although some studies in adults have experimentally examined the effects of breakfast consumption compared with omission on physical activity, findings appear to be limited to only two studies (Betts et al., 2014, Halsey et al., 2011). These studies have produced inconsistent results, perhaps due to differences in methodology, and cannot be applied to younger populations.

Overall, experimental evidence on the effects of breakfast on subsequent energy intake and physical activity in young people is sparse and remains inconclusive in adults. It is clear that more research is needed in children and adolescents in particular, as the prevalence of breakfast skipping increases from childhood to adolescence (Timlin et al., 2008), and as majority of the findings are based on studies in adults. Adolescence is a critical period to encourage the establishment of health-promoting behaviours, such as breakfast consumption, as eating habits develop at a young age and track into the adulthood, when changing the habits becomes increasingly difficult (Cohen et al., 2003). Furthermore, studies in young people and adults have not directly compared overweight and non-overweight populations, despite some data suggesting that any observed effects could depend on weight status (Berkey et al., 2003).

2.8 Summary

Overweight and obesity in young people has reached epidemic levels, encouraging research to identify factors that have an impact on energy balance. Breakfast is commonly considered a key component to improved diet and nutritional status of children and adolescents. Despite such benefits, breakfast consumption has declined among young people over recent decades. Breakfast skipping is particularly common among adolescent girls. Previous research has repeatedly demonstrated an inverse relationship between breakfast and BMI and adiposity in children and adolescents. Although breakfast skippers are more likely to be overweight or obese, their daily energy consumption is either not different or lower than of those who regularly eat breakfast. Therefore, energy expenditure and physical activity may be more important in explaining the inverse relationship between breakfast consumption and obesity than energy intake. However, the available epidemiological literature on breakfast and its associations with BMI, dietary intakes and physical activity remains inconclusive and indicates a great lack of experimental evidence for a better understanding of how breakfast could be used as a potential intervention for preventing and managing obesity in young people.

3 Methods

3.1 Participants

After gaining ethical approval from the University of Bedfordshire Research Ethics Committee, girls aged 12 to 15 years of age were invited to participate in the study. A sample of 33 volunteers was recruited from middle and upper schools in the Bedford and Luton areas. Prior to any testing, a parental informed consent form, child assent form and Health Screen and Lifestyle Questionnaire were gained from the participants and their parents/guardians. Girls were excluded from the study if they had health related issues identified from the Health Screen Questionnaire (e.g. allergies or intolerances to the breakfast meals). Participants who were unable to walk or wear a physical activity monitor on their wrist, those with a pacemaker, and those without parental consent or who did not provide child assent were also excluded from the study.

3.2 Preliminary measurements

Standing and sitting height, body mass and body fat, body mass index (BMI) and waist circumference were taken from all participants before the trials. Standing and sitting height were measured to the nearest 0.1 cm using a portable Leicester height measure (Holtain Ltd., Dyfed, UK). When measuring sitting height, the subjects were instructed to sit on a stool resting lightly against stadiometer. Sitting height was calculated from the height of the stool subtracted from the total height. Body mass was measured to the nearest 0.1 kg and body fat (%) using a Tanita Body Composition Analyser (BC-418 MA, Tanita Corporation, Tokyo, Japan). The participants' BMI was calculated as body mass divided by height squared (kg/m^2). Using age and sex-specific cut points (Cole et al. 2000), the girls were then classified as non-overweight and overweight according to their BMI. Waist circumference was measured on exhalation to the nearest 0.1 cm using an inelastic tape measure (make: rollfix, HaB direct, UK) at the midpoint between last rib and the top of the iliac crest. All measurements were taken twice. If there was 0.5 difference in centimetres or kilograms or 2% difference in percentage of body fat between the two readings, a third measurement was taken. The girls were also asked to provide a self-assessment of their physical maturation using secondary sexual characteristics (Tanner, 1962), and to complete a Lifestyle

Questionnaire containing questions on their breakfast habits. Habitual breakfast consumption was measured using the Lifestyle Questionnaire, where participants reported on how many weekdays and weekends they usually consume breakfast. To distinguish between breakfast consumers and breakfast skippers, a 5-day cut-off was employed previously used by Pearson et al. (2009). Participants were therefore defined as frequent breakfast consumers (consume breakfast ≥ 5 days a week) or infrequent breakfast consumers (consume breakfast < 5 days a week).

3.3 Experimental design

Using a repeated measures design, participants completed three, 3-day trials: control (habitual) breakfast (CON), no breakfast (NB), and high-energy breakfast (HEB). The conditions (CON, NB and HEB) were conducted in a counter-balanced order, and all conditions were conducted across the same three day period over three weeks. The energy intake of the breakfast was manipulated for the NB and HEB conditions (Table 1).

Table 1: Study design with three, 3-day trials.

Condition	Breakfast Energy Content			Outcome variables (assessed across 3 days)
	Day 1 (Tuesday)	Day 2 (Wednesday)	Day 3 (Thursday)	
CON	N/A	N/A	N/A	Food diary (dietary intakes) Accelerometry (physical activity)
NB	0 kJ (0 kcal)	0 kJ (0 kcal)	0 kJ (0 kcal)	
HEB	1994 kJ (475 kcal)	1994 kJ (475 kcal)	1994 kJ (475 kcal)	

Abbreviations: CON = control (habitual breakfast); NB = no breakfast; HEB = high-energy breakfast.

On the morning of the trials, participants arrived at school before first lesson in the fasted state (no food or drink consumed except water for the previous 12 hours) during the HEB and NB conditions. Participants then consumed either NB or HEB. For CON, the participants were not told to fast and had already consumed their habitual breakfast. The girls were asked to consume all of the breakfast provided within 30 minutes. Following breakfast they were asked to continue with their normal daily routine and to record their diet with a digital camera and written food diary, while wearing the accelerometer provided. All equipment (digital camera, food diary and accelerometer) was given to the girls the day prior to each trial (i.e. the Monday of each main trial week). Each morning, the girls met with the research team at 'breakfast club' where the participants' food diaries were checked for completion, cross-referenced with the corresponding meal photographs, and any details added to the diary if required. A visual aid (Young Person's Food Atlas, Foster et al., 2010) was used to estimate the portion size if a participant did not take photographs of all foods and beverages consumed on the previous day.

3.4 Compositions of the breakfast meals

The amount and energy content of food and beverages consumed at breakfast for each condition is displayed in Table 2. The participants were required to eat all food and drink all juice/or water served during the HEB and NB conditions. Average values are provided for the CON condition.

Table 2. Amount, energy content and nutrient information of CON, HEB and NB.

Condition	Description	Macronutrient content
CON	Habitual breakfast consumed by participants	672 kJ(161 kcal) 27.1 g CHO, 3.8 g fat, 4.5 g protein, 1.2 g fibre
NB	375 ml water	0 kJ (0 kcal)
HEB	56.3 g wheat biscuits (Weetabix, Kettering, UK), 188 ml semi-skimmed milk (Tesco Stores Ltd, Chestnut, UK), 375 ml orange juice (Tesco Stores Ltd, Chestnut, UK)	1994 kJ (475 kcal) [a], 89.3 g CHO [a], 5.6 g fat [a], 16.8 g protein [a], 5.9 g fibre [a]

[a] significantly higher compared with NB and CON

A 475 kcal breakfast of wheat biscuits served with milk and a glass of orange juice were selected for the breakfast condition in this study for various reasons. First, the foods, such as Weetabix, provided for breakfast constituted a 'healthy breakfast', i.e. wholegrain, high in fibre breakfast with no added sugar and low in fat (as discussed in Chapter 2: '2.4.3 Effect of type of breakfast'). Also, with limited kitchen facilities it was not possible to serve foods that would require cooking, such as porridge. Total amount of energy provided in the high-energy breakfast was 475 kcal. In the previous breakfast intervention study by Kral et al. (2010), 8-10-year-old children were served breakfast consisting of 350 kcal, therefore considering that the participants in this study were of older age (12-15 years) and to increase the likelihood of an effect of breakfast on subsequent energy intake and physical activity, the breakfast the present study was chosen to be a higher value than 350 kcal. In addition, based on previous studies in adults, a high-energy breakfast consisting of 630 kcal (Levitsky and Paconowski, 2013) and 700 kcal (Martin et al., 2000) has shown to reduce energy intake later in the day. Further, a cross-sectional study by Nicklas et al. (2000) reported that average energy intake consumed at breakfast in 15-year olds was 437 kcal, thus the amount of energy provided in high-energy breakfast in this study was increased to 475 kcal. The amount (kcal content) of breakfast provided was in absolute terms, rather than relative to body mass, which is consistent with previous research (e.g. Kral et al, 2010; Levitsky and Paconowski, 2013) and enables direct relations to nutritional recommendations which are also provided in absolute terms.

3.5 Dietary assessment

During each 3-day trial, the participants were instructed to complete a 3-day food diary on three consecutive school days, where they were asked to report the day and time of all foods and drink consumed, brand of the food, description of the food - including preparation method, portion size (an estimate, e.g. a bowl, a handful, etc) and any leftovers. Prior to each trial, the girls received a digital camera (Vivitar, ViviCam 46, China) and were instructed to photograph all foods and beverages consumed during the period of a trial and use photographs as a recall method when completing their food diaries. During the preliminary testing, the participants received a tutorial on using the digital cameras, completing their food diaries, and were given written instructions to accompany the tutorial. Amounts (grams) of each food item were estimated by comparing the digital photographs taken by the participants' with the Young Person's Food Atlas (Foster et al., 2010). The Young Person's Food Atlas allows the researcher to estimate the food portion size both before and after the participant has eaten. If the photograph was missing of a certain food item or a meal, the estimation of the portion size was based on portion size identified by participants in the Food Atlas. The use of food photographs to estimate food portion size has been shown to increase the accuracy of food portion size estimation compared with unaided estimates (Martin et al., 2007). Macronutrient content – total carbohydrates, fibre, fat and protein (in grams and in percentage of total daily energy intake) of the dietary intake was also computed for each participant. The 3 day food diaries were subsequently analysed using industry standard software (Dietplan 6.70, Forestfield Software, Horsham, UK) to estimate nutrient and energy intake (kJ/d) of the participants.

To examine whether any effects of breakfast were dependent on the time of day, dietary intakes were categorised into three time periods (Dubois et al., 2008): (i) early morning 06.00-9.00 (including breakfast and early morning snacks), (ii) late morning-afternoon 9.00-14.00 (including afternoon snacks and school lunch), and (iii) afternoon-evening 14.00 until bedtime (including dinner and evening snacks). Energy intake was computed for each time period, morning and afternoon-evening time periods together (i.e. energy intake excluding breakfast) and total daily energy intake for all three time periods.

To estimate daily fruit and vegetable consumption, the total number of portions was counted using National Health Service (NHS) guidelines for 5 portions per day (5 a day portion size guide, NHS). High-fat and sugary snacks were defined as sweet baked goods, cookies, ice cream, cakes, desserts, jams, sugar, sweets, nuts, potato crisps, cheese products, popcorn and soft drinks (Sjöberg et al., 2003). The number of snacks was then counted for each day and condition.

To be included in the dietary intake analysis the participants were required meet the following criteria: (i) to provide full dietary intakes over 3 days for each of the 3 conditions, (ii) to attend the breakfast club in a fasted state for 3 days during NB, (iii) if the high-energy breakfast was not fully consumed, it had to represent at least 20% of total daily energy intake. If the participant failed to meet one of the criteria, she was excluded from the dietary analysis.

3.6 Physical activity assessment

Wrist-worn accelerometers (GENEActiv, ActivInsights Ltd., Kimbolton, UK) were employed to assess participants' physical activity levels during each 3-day condition. The accelerometers were set to record at 85.7 Hz. using a 1-second epoch. The girls were instructed to wear the accelerometers on their non-dominant wrist for three days at all times and were given written instructions. To estimate the time spent in sedentary, light, moderate and vigorous intensities, GENEActiv cut-points previously established by Phillips et al. (2013) were applied. To explore whether any effects of breakfast were dependent on the time of day, similar to meal patterns, physical activity data was split into three time periods: i) early morning 6.00-9.00 hrs, (ii) late morning-afternoon 9.00-14.00 hrs, and (iii) afternoon-evening 14.00-21.00 hrs.

To be included in the physical activity statistical analysis the participants had to meet following criteria: (i) to wear physical activity monitor continuously for 3 days during each condition, (ii) to abstain from all food and drink until 09.00 hrs for NB, condition (iii) if high-energy breakfast was not fully consumed, it had to represent at least 20% of total daily energy intake. If a participant failed to meet one of the criteria, she was excluded from the physical activity analysis.

3.7 Statistical analyses

Statistical analyses were completed using SPSS software version 21. Shapiro–Wilk tests were used to confirm normal distribution. The homogeneity of variances was confirmed by Mauchly's test of sphericity, and a Greenhouse–Geisser correction was applied to the degrees of freedom if the sphericity assumption was violated. Condition by day (3 x 3) repeated measures analysis of variance (ANOVA) were used to examine differences in all outcome variables (dietary intakes and physical activity) between the three, 3-day trials. Differences in dietary and physical activity variables were examined between conditions, and interactions with weight status and habitual breakfast consumption were explored. When there was a main effect of condition, post hoc pair-wise comparisons were performed using the Bonferroni method. Effect sizes (ES) were calculated for differences were significant or approached significance (defined as $P \leq 0.101$) for the main outcome variables. Student's independent t-tests were used to compare anthropometric characteristics by group (overweight vs. non-overweight; frequent vs. infrequent breakfast consumers). Statistical significance was accepted at $P \leq 0.05$.

4 Results

4.1 Participant characteristics

A total of 33 girls participated in the study. Nine participants were excluded from statistical analyses of the dietary outcome variables for the following reasons: three participants ate on NB condition, one participant ate too little during high-energy breakfast condition (less than 20% of total daily energy intake) for three days and five participants did not keep the record of their dietary intake for one or more condition. Anthropometric characteristics and habitual breakfast habits (frequent or infrequent breakfast consumer) of the 24 participants used for final analyses are shown in Table 3.

Table 3. Participant characteristics of overweight (OW) and non-overweight (NO) girls (*n* = 24) [a]

Characteristic	OW (*n* = 9)	NO (*n* = 15)	Combined (*n* = 24)
Age (yrs)	13.2 ± 0.7	13.7 ± 0.9	13.6 ± 0.8
Stature (m)	1.6 ± 0.1	1. 6 ± 0.1	1.6 ± 0.1
Body Mass (kg) [b]	65.9 ± 14.8	49.5 ± 9.8	55.6± 14.2
Body Fat (%) [b]	35.3 ± 5.7	25.7 ± 4.2	29.3 ± 6.7
WaistCircumference (cm) [b]	72.9 ± 11.8	63.9 ± 7.1	69.6± 11.7
BMI ($kg \cdot m^{-2}$) [b]	25.9 ± 4.2	19.1 ± 2.7	21.6 ± 4.6
Tanner(breast development)	4.3 ± 0.7	3.5 ± 0.9	3.9 ± 0.8
Tanner (pubic hair)	4.4 ± 0.5	3.8 ± 0.6	4.1 ± 0.6
Breakfast habits (*n*)			
Frequent	4	9	13
Infrequent	5	6	11

[a] Mean ±SD (age, stature, body mass, body fat, waist circumference, BMI, Tanner).
[b] Between OW and NO significant difference (P≤0.05).

The was no significant difference between frequent and infrequent breakfast consumers in body mass, BMI, body fat, waist circumference and Tanner (BD and PH) measurements (P>0.05).

4.2 Effects of breakfast on dietary intake

4.2.1 Total energy intake

There was a significant main effect of breakfast condition on total daily energy intake (*P*=0.001, ES: 0.63), independent of day (trial by day interaction: P=0.751). Post hoc analysis revealed that daily energy intake was significantly higher in HEB compared with NB (*P*=0.001) and CON (P=0.002). This effect was independent of weight status (P=0.818) but did depend whether the participant was a frequent or infrequent breakfast consumer (trial by breakfast habits interaction: P=0.001). Frequent breakfast consumers had significantly higher daily energy intakes in CON (P=0.045) and HEB (P=0.007) compared with NB. Infrequent consumers had significantly higher daily energy intakes in HEB compared with both CON (P=0.001) and NB (P=0.017) (Figure 1).

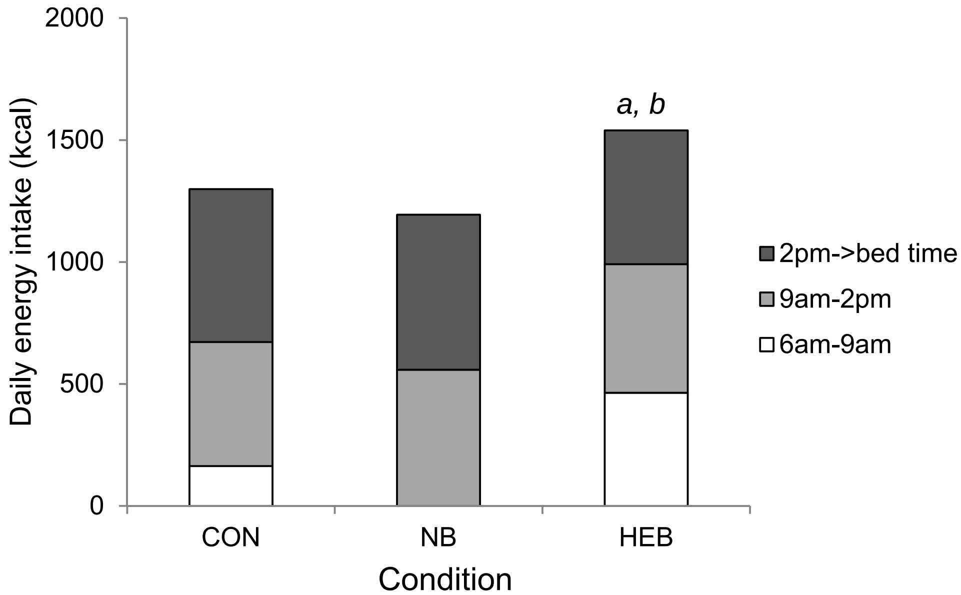

Figure 1. Energy intake (average of 3 days) during different periods of the day for the control (CON), no breakfast (NB) and high-energy breakfast (HEB) conditions. [a] total daily energy intake higher in HEB and CON compared with NB in frequent breakfast consumers; [b] higher in HEB compared with NB and CON in infrequent breakfast consumers (*P*<0.05).

4.2.2. Energy intake for the remainder of the day

As indicated in Table 4, there was no significant main effect of breakfast (P=0.49) on energy intake consumed between 09.00 hrs and 14.00 hrs. Hence, the participants consumed similar amount of calories during this time period after consuming habitual breakfast, high-energy breakfast or omitting breakfast. There was also no significant main effect of breakfast (P=0.101, ES: 0.31) on energy intake consumed between 14.00 hrs and bedtime. The intake of energy was lower in HEB but not significantly compared with CON (P=0.307) and NB (P=0.194).

Table 4. Energy intake (average of 3 days) consumed between 09.00 - 14.00 and 14.00 until bedtime in control (CON), no breakfast (NB) and high-energy breakfast conditions (*n*=24) [a]

Time period	Energy intake		
	Control	NB	HEB
09.00-14.00			
	2192±736 kJ (524±176 kcal)	2372±640 kJ (567±153 kcal)	2230±658 kJ (533±157kcal)
14.00-bedtime			
	2598±832 kJ (621±199 kcal)	2732±1037 kJ (653±248kcal)	2385±782 kJ (570±187 kcal)

[a] All values are means and ±SDs.

4.3 Macronutrient intake

There was significant main effect of breakfast condition on fibre (*P*=0.001, ES: 0.97), fat (*P*=0.001, ES: 0.82), carbohydrate (*P*=0.001, ES: 0.99) and protein (*P*=0.001, ES: 0.98) intakes between 06.00 and 09.00. The intakes of carbohydrate, fibre, fat and protein were significantly higher in HEB (*P*<0.05) compared with CON and NB. When expressed as percentage of energy intake consumed between 06.00 and 09.00, more energy was consumed from fat (22.7%±10.7 vs. 11.2%±1.9; *P*=0.002, ES: 0.60) in CON compared with HEB, and more energy from carbohydrate (74.9%±1.3 vs. 66.0%±9.7; *P*=0.001, ES: 0.70) and from protein (14.0%±1.0 vs. 11.2%±3.8; *P*=0.005, ES: 0.59) in HEB than in CON.

There was main effect of breakfast on total daily carbohydrate (*P*=0.0001, ES: 0.75), fibre (*P*=0.001, ES: 0.75) and protein (*P*=0.004, ES: 0.47) intakes. Total daily carbohydrate intake was higher in HEB compared with CON (*P*=0.001) and NB (*P*=0.001). Total daily fibre intake was higher in HEB compared with CON (*P*=0.001) and NB (*P*=0.001). Total daily protein intake was higher in HEB compared with CON (*P*=0.036) and NB (*P*=0.015). These effects were independent of weight status or habitual breakfast consumption for total fibre and protein intake (*P*>0.05), but depended on habitual breakfast consumption (*P*=0.004) for total carbohydrate intake. Frequent breakfast consumers had significantly higher carbohydrate intakes in CON

(*P*=0.017) and HEB (*P*=0.001) compared with NB. Infrequent breakfast consumers had significantly higher carbohydrate intakes in HEB compared with CON (P=0.001) and NB (*P*=0.008). There was no main effect of breakfast condition on total fat intake (*P*=0.607, ES: 0.15), nor for any of the individual macronutrient intakes when confined to the period after breakfast (*P*>0.05). When expressed as percentage of total daily energy intake there was significant main effect of breakfast condition on energy consumed from fat (*P*=0.001, ES: 0.64) and carbohydrate (*P*=0.001, ES: 0.65). Less percentage of energy from fat was consumed in HEB compared with CON (*P*=0.001) and NB (*P*=0.001), and more percentage of energy from carbohydrate was consumed in HEB compared with CON (*P*=0.001) and NB (*P*=0.001). There was no effect of breakfast on total protein intake (*P*=0.261) when expressed as a percentage of total daily intake (Table 5).

Table 5. Macronutrient consumption (average of 3 days) in control (CON), no breakfast (NB) and high-energy breakfast conditions (HEB): total daily consumption, 09.00-14.00 and 14.00 until bedtime (*n*=24) [a]

Nutrient	CON			NB			HEB		
	Total	09.00-14.00	14.00-	Total	09.00-14.00	14.00-	Total	09.00-14.00	14.00-
Carbohydrate (g)	167.9± 9.9 [b c]	66.2± 5.6	74.6± 6.0	144.8± 8.7 [b c]	70.0± 5.6	74.8± 6.0	235.1± 12.3[b c]	76.9± 7.0	70.6± 7.0
Fibre (g)	8.5± 0.7 [b]	3.5± 0.3	3.5± 0.4	7.1± 0.6 [b]	3.8± 0.4	3.3± 0.4	12.8± 0.7 [b]	3.5± 0.4	3.7± 0.4
Fat (g)	49.1± 3.7	21.0± 1.8	24.1± 2.7	45.5± 3.8	20.1± 1.9	25.4± 2.5	49.8± 4.2	19.0± 1.8	25.0± 3.1
Protein(g)	47± 2.5 [b]	15.5± 1.1	27.7± 2.9	48.0± 3.0 [b]	17.1± 1.4	31.0± 2.5	62.5± 4.9 [b]	16.8± 2.0	29.5± 3.5
Carbohydrate (% of energy)	50.1± 12.4 [d]	48.1± 10.0	48.2± 8.7	49.6± 8.8 [d]	49.2± 13.0	45.6± 11.7	58.1± 3.8 [d]	55.4± 9.8	45.7± 8.7
Fat (% of energy)	31.3± 8.8 [e]	35.5± 8.5	32.1± 7.8	33.7± 6.9 [e]	32.0± 10.9	33.8± 10.2	26.8± 3.9 [e]	31.4± 9.0	33.7± 6.8
Protein (% of energy)	14.4± 8.7	12.2± 5.6	18.± 6.7	16.7± 5.4	11.9± 5.2	16.2± 5.6	15.2± 3.1	11.8± 4.4	20.6± 8.9

[a] All values are means and ±SDs

[b] Total daily carbohydrate, fibre and protein intake was higher in HEB compared with CON (*P*<0.05) and NB (*P*<0.05).

[c] Frequent breakfast consumers had significantly higher carbohydrate intakes in CON (*P*=0.017) and HEB (*P*=0.001) compared with NB. Infrequent breakfast consumers had significantly higher carbohydrate intakes in HEB compared with CON (*P*=0.001) and NB (*P*=0.008).
[d] More energy from carbohydrate was consumed in HEB compared with CON (*P*=0.001) and NB (*P*=0.001)
[e] Less energy from fat was consumed in HEB compared with CON (*P*=0.001) and NB (*P*=0.001).

4.5 Fruit & vegetable and high-fat & sugary snack consumption

There was no main effect of breakfast on daily fruit & vegetable (P=0.21) and snack (P=0.33) consumption. The average number of portions of fruits and vegetables consumption per day was 1.2±1.0 in CON, 0.8±0.2 in NB and 0.9±0.8 in HEB. The average amount of snacks per day was 2.8±1.2 in CON, 2.8±1.5 in NB and 2.3±1.3 in HEB.

4.6 Effects of breakfast on physical activity

The same participants (except for one) who were excluded from the dietary analysis were also excluded from statistical analyses of the physical activity variables (three participants who ate during NB, one who ate too little in HEB, and four who were missing dietary records); in addition, another three were excluded as they did not wear the accelerometer as required. One participant who was missing dietary records from HEB and thus excluded from dietary analysis, was still included in the physical activity analysis as she attended breakfast club on 3 days, consumed the high-energy breakfast and wore her accelerometer as required. Thus, data of 22 participants were included in the physical activity analysis.

As demonstrated in Table 6 there was no main effect of breakfast on time spent in sedentary (*P*=0.410), light (*P*=0.444), moderate (*P*=0.344) and vigorous (*P*=0.672) physical activity across conditions.

Table 6. Sedentary, light, moderate and vigorous physical activity (average of 3 days) between 09.00-14.00 and 14.00-21.00 in control (CON), no breakfast (NB) and high-energy breakfast conditions (*n*=22) [a] in minutes (min) and percentages (%) time

	CON		NB		HEB	
	09.00-14.00	14.00-21.00	09.00-14.00	14.00-21.00	09.00-14.00	14.00-21.00
Sedentary						
(min)	209±16	295±32	210±12	301±23	211±19	295±23
(%)	70±5	70±8	70±4	71±5	70±2	70±6

Light						
(min)	121±7	94±24	116±8.7	91±17	118±7	94±15
(%)	24±4	22±6	24±2	22±4	24±4	22±4
Moderate						
(min)	17±7	27±8.5	16±6	25±7	15±7	26±9
(%)	6±2	6±2	5±2	6±2	5±2	6±2
Vigorous						
(min)	2±1	3.4±2	2±2	3±2	2±5	4±3
(%)	0.6±0.4	0.8±0.5	0.8±0.6	0.8±0.5	0.7±0.8	0.9±0.6

[a] All values are means and ±SDs

When expressed as percentage of total daily physical activity, there was no main effect of breakfast condition on sedentary (*P*=0.446), light (*P*=0.481), moderate (*P*=0.317) and vigorous (*P*=0.685) activities between 9.00 and 21.00 across conditions.

5 Discussion

Over past decades the increased prevalence of overweight and obesity among young people in the UK and around the world has reached alarming figures (HSE, 2013) and is a growing health concern (Timlin et al., 2008). Overweight and obesity track into adulthood increasing the risk of cardiovascular and metabolic diseases (Deshmukh-Taskar et al., 2010). Since weight gain is a result of imbalance in energy intake and energy expenditure, dietary habits and physical activity may contribute to the incidence of overweight and obesity in young people (Frieden et al., 2010). Breakfast skipping and physical inactivity have been found to be positively associated with higher adiposity in young people, and increase between childhood and adolescence (Berkey et al., 2003). Childhood and adolescence are critical periods of establishing lifestyle behaviours (Cohen et al., 2003), however, surprisingly, little research has investigated the causality between the effects of breakfast consumption on daily energy intakes and physical activity in young people.

This study was the first to investigate the effects of breakfast consumption compared with omission on a range of dietary variables and on physical activity in overweight and non-overweight adolescent girls. Unlike in previous research (Kral et al. 2011), in this study the diet of the participants was assessed over three days in free-living conditions rather than 1-day protocols and *ad libitum* buffet meals, which do not reflect habitual diet. This study aimed to substantially progress the evidence on breakfast consumption and health in young people by attempting to establish causality between the effects of breakfast on dietary intakes and physical activity, and to examine possible interactions with weight status and/or habitual breakfast consumption. The main findings were that consuming a high-energy breakfast containing ~475 kcal for three consecutive days did not reduce subsequent daily energy intake (energy intake after breakfast) when compared with consuming no breakfast or the participant's habitual breakfast (control) in adolescent girls. This lack of dietary compensation resulted in higher total daily energy intakes during the breakfast condition, due to the added calories consumed at breakfast. Although not significant, it may be noteworthy that the participants consumed 83 fewer kcal in the afternoon/evening (14:00-bedtime) during the high-energy breakfast compared with no breakfast condition, suggesting future research with larger sample sizes may be required to further investigate the effect of breakfast consumption and omission on energy intakes later in the day specifically. The higher daily energy intake during the high-energy breakfast condition was due to higher intakes of carbohydrate, protein and fibre compared with the no breakfast and control conditions, with no effect on total fat intake. When macronutrient content was expressed as percentage of total daily energy intake, less energy from fat and more energy from carbohydrate was consumed in the high-energy breakfast condition compared with the no breakfast and control conditions. Breakfast consumption or omission had no effect on fruit and vegetable consumption and on number of snacks consumed by the girls later in the day. The breakfast manipulation did not affect time spent in sedentary, light, moderate or vigorous physical activity in this sample of adolescent girls.

5.1 Effects of breakfast on energy intake

Consumption of a high-energy breakfast resulted in an overall increased daily energy intake during the high-energy breakfast condition by approximately 360 kcal compared with no breakfast condition and 270 kcal compared with control condition. Frequent breakfast consumers had similar total daily energy intakes in control and high-energy breakfast conditions, which were both higher than during no breakfast condition. This was different for infrequent breakfast consumers as their total energy intakes were similar in the control and no breakfast conditions (since they would not normally consume breakfast during control condition). Therefore, infrequent breakfast eaters had higher daily energy intakes in high-energy compared with control and no breakfast conditions. This finding confirms and extends results from previous cross-sectional studies that demonstrated higher daily energy intakes in children and adolescents who regularly consume breakfast than those who skip breakfast (Timlin et al., 2008).

The present experiment demonstrated that overweight and non-overweight adolescent girls aged 12-15 did not compensate by consuming more energy during the remainder of the day when omitting breakfast compared with consuming a high-energy breakfast for three days under free-living conditions, despite the breakfast containing 475 kcal. These results are consistent with those reported by Kral et al. (2010) where children aged 8-10 did not consume more calories at lunch or for the remainder of the day when omitting compared with consuming breakfast on a single occasion. The present study extended these findings to adolescent girls and assessed possible interactions with weight status and breakfast habits. Also, the dietary intake was assessed over three days rather than one day protocol and in free-living conditions which give a better representation of habitual diet compared with *ad libitum* meals in laboratory conditions. Further, breakfast energy intake was manipulated in this study by comparing habitual, high-energy breakfast and no breakfast conditions rather than only examining the effects of breakfast consumption compared with omission. There was no difference in energy intake for the remainder of the day between overweight and non-overweight girls, or between frequent and infrequent breakfast consumers. Contrary to this finding, Halsey et al. (2011) found that females who were regular breakfast consumers consumed significantly more food and later in the day during no breakfast condition.

However, the study examined adults who were required to fast until mid-day during no breakfast condition for one week, which may not be possible with samples of young people for ethical reasons. Indeed, the girls in the present study were free to eat as they pleased from 09:00 onwards.

Evidence suggesting that there is no dietary compensation later in the day has been presented in studies in adults (Betts et al., 2014, Halsey et al., 2011, Levitsky and Paconowski, 2013). However, it was observed that energy intake was 83 kcal and 51 kcal lower in the late afternoon-evening, though not significant, during high-energy breakfast condition compared with no breakfast and habitual condition respectively in this study. Kral et al. (2010) suggested that by increasing the sample size in their study the effect of breakfast on energy intake at lunch would reach statistical significance; this may also be the case with regards to energy intake specifically in the afternoon/evening period in the present study. It is also of interest that when energy intake between 14.00 and bedtime was examined for each participant, 46% of the girls consumed 100 kcal more during no breakfast compared with high-energy breakfast condition, with more than a third of these girls consumed more than 150 kcal during no breakfast condition. This inconsistency in findings indicates that further research perhaps consisting of a larger sample size is required.

The breakfast provided during high-energy breakfast condition was purposefully chosen to contain ready-to-eat cereal and wholegrain. Importantly, ready-to-eat-cereals have been found to have a positive effect on nutrient intakes, including decreased fat consumption (Barton et al., 2005). Therefore, it is noteworthy that only 25% of girls who were identified as frequent breakfast eaters usually consumed cereal for their habitual breakfast. Breakfast provided during high-energy breakfast condition and habitual breakfast of the participants (control condition) differed significantly in macronutrient content. The amount of carbohydrate, fibre, total fats and protein was greater in high-energy breakfast compared with habitual breakfast. This difference was due to considerably larger breakfast served during high-energy breakfast condition than the participants normally ate (161 kcal on average in control compared with ~475 kcal in high-energy breakfast). However, when expressed as percentage of energy consumed at breakfast, the girls' habitual breakfasts contained more energy from fat and less energy from carbohydrate and protein when compared with high-energy breakfast. A possible explanation for the slightly reduced energy intake between 14.00 and bedtime during high-energy breakfast condition may be due to the high-energy breakfast containing more fibre and carbohydrate. It is likely that high-fibre breakfast containing wholegrain may have prolonged satiety in the present study. The possible mechanisms of prolonged satiety may relate to slower digestion and transit time of food in the gut, and delayed gastric emptying (Anderson et al., 2009). In the small intestine, fibre can evoke responses of several gastrointestinal hormones that stimulate a reduction in blood glucose level and an increase in insulin release leading to a more stable blood glucose levels throughout the morning, with a steady release of glucose into the blood and thereby affecting appetite (Anderson et al., 2009). As well, the breakfast may have affected hormones that influence appetite in response to the ingested food, such as GLP-1 which is released in response to the presence of carbohydrate (Anderson et al., 2003), PYY which reduces appetite and ghrelin that stimulates food intake (Parnell and Reimer, 2009). The high-energy breakfast was also higher in protein compared with participants' habitual breakfast; protein, in turn, leads to greater satiety than carbohydrate and fat (Anderson and Woodend, 2003). However, subjective hunger ratings after breakfast consumption and prior subsequent meals were not measured in the present study, therefore it is not possible to draw any conclusions whether the girls did experience prolonged satiety after consuming a high-energy breakfast.

Since the girls in the present study were not considered to be underweight and included a mixture of overweight and non-overweight participants, it is likely that the low energy intake values reported by participants were due to underreporting. The average daily energy intake of the participants in the present study was 1303±321 kcal in control, 1210±305 kcal in no breakfast and 1567±298 kcal in high-energy breakfast condition. These values are notably lower than those recommended for adolescent girls. Estimated average requirement values for energy (population values, assuming average activity levels) for 12-15-year-old girls range between 2100 - 2390 kcal (Scientific Advisory Committee on Nutrition, 2011). Previous studies have found that overweight and obese participants underreport their energy intake (Heitmann and Lissner, 1995) in order to convey a socially desirable image (Macdiarmid and Blunde, 1998); this problem may have affected our results, particularly since approximately 40% of the sample in this study consisted of overweight participants. It is also possible that some participants were dieting at the time of the experiment which can lead to underreporting of food intake (Macdiarmid and Blunde, 1998), although dieting habits were not assessed in the present study.

5.2 Effects of breakfast on carbohydrate, fibre, fat and protein intakes

During the high-energy breakfast condition, daily intakes of carbohydrate, fibre and protein in grams were higher than in control and no breakfast conditions, mainly due to the consumption of the high-energy breakfast. Fat intake was similar across conditions, despite the high-energy breakfast containing more fat (as well as carbohydrate, protein and fibre) than the participant's habitual breakfasts consumed in the control condition. The effect of the breakfast manipulation on total carbohydrate intake depended on whether the participant was classified as a frequent or infrequent breakfast eater: frequent breakfast consumers had greater carbohydrate intakes in high-energy and habitual breakfast conditions compared with no breakfast, whereas infrequent breakfast consumers had higher carbohydrate intakes in high-energy breakfast compared with both control and no breakfast conditions. These results are different to the cross-sectional findings reported by Dubois et al. (2007) who found that pre-schoolers classified as breakfast eaters and skippers had similar total carbohydrate intakes and Sjöberg et al. (2003) who reported that girls aged 15-16 regardless of their breakfast habits (regular vs. irregular breakfast consumers) consumed similar amount of carbohydrate. Dubois et al. (2007) and Sjöberg et al. (2003) also found that breakfast eaters have higher total protein intakes than those children who skip breakfast. In the present study, there was no difference between conditions in protein, fibre and fat intakes for the remainder of the day. Similar amount of fat consumed by breakfast eaters and skippers was previously found in observational studies (Dubois et al., 2007, Sjöberg et al., 2003). However Sjöberg et al. (2003) reported higher total fibre intake by girls who were regular breakfast consumers compared to irregular breakfast eaters. In the present study, total daily fibre intake was higher in high-energy breakfast condition compared with no breakfast condition, therefore suggesting that there might be a causal link between total daily fibre intake and breakfast consumption. It is noteworthy that in this study the values for carbohydrate, fibre, fat and protein were lower than in those presented by Dubois et al. (2007) and Sjöberg et al. (2003), possibly due to great likelihood of underreporting by the participants. When carbohydrates, fat and protein were expressed as percentage of total energy intake the results appeared to be different to absolute values in grams. Energy consumed from carbohydrate was higher in high-energy breakfast compared with habitual and no breakfast conditions. This is in accordance with some previous research demonstrating that breakfast consumers have higher percentage of energy intake from carbohydrate (Deshamukh-Taskar et al., 2010), Nicklas et al., 2000), however Deshamukh-Taskar et al. (2010) documented this difference in children and adolescents only who were RTEC eaters. Therefore, the present study suggests that the association between breakfast consumption and carbohydrate intake may be causal, especially if it is a cereal-based breakfast. The girls consumed significantly more energy from fat during control and no breakfast conditions than during high-energy breakfast condition. In agreement, Nicklas et al. (2000) documented that percentage of total daily energy intake was higher from fat in adolescents who skipped breakfast. The present study extends these findings by inferring the nature of this relationship is causal; thus, consuming a relatively high-energy breakfast for three days can directly cause adolescent girls to consume diets that comprised of a lower percentage of fat. Current guidelines for carbohydrates, total fat and protein intake are 50% of energy intake from carbohydrate, no more than 35% from fat and 15% from protein (Food Standard Agency, 2007). During habitual and high-energy breakfast conditions the participants demonstrated different macronutrient profiles than during no breakfast condition when they consumed more energy from fat (34% in NB vs. 31% in CON vs. 26% in HEB) and protein (17% vs. 14% vs. 15%) than during two other conditions. There is some evidence suggesting that fat intake is associated with adiposity in children indicating that fat intake is higher in obese compared with non-obese children (McGloin et al., 2004), although it is energy intake that contributes to obesity rather fat intake, as high energy intake shifts to positive energy balance which in turn leads to overweight and obesity (Troiano et al., 2000). However, reducing fat intake may have benefits relating to health such as reduced LDL levels (Nordmann et al., 2006) that are independent of energy intake. Moreover, Reinehr et al. (2005) found that weight loss as a result of low-fat high-carbohydrate diet in obese children did not change ghrelin secretion, but decreased leptin – hormone made by fat cells regulating adipose stores in the body and improved insulin resistance. In the present study, the girls consumed significantly less fat and more carbohydrate during high-energy breakfast condition compared with habitual and no breakfast, thereby suggesting, that high-energy breakfast resulting in lower fat intake may be recommended to children and adolescents who could benefit from lowering their fat intake for health reasons (e.g. to reduce cholesterol levels).

Excluding breakfast, the macronutrient composition of the diet remained identical in all three conditions when expressed as amounts (in grams) or percentages of total daily intake. Kral et al. (2010) reported similar results regarding fat intake in children: percentage of energy intake from fat was similar at lunch and for the remainder of the day in no breakfast and breakfast conditions. However, when the results were expressed as percentages of total daily intakes and included the breakfast meal, high-energy breakfast made a positive contribution to the overall diet by a better distribution of macronutrients: less energy was consumed from fat and protein and more energy from carbohydrate. In addition, although still below the recommended 18 grams of fibre a day (Food Standard Agency, 2007), the high-energy breakfast made a significant contribution to daily fibre intakes, which increased from 7.1 g and 8.5 g in the no breakfast and habitual breakfast conditions, respectively, to 12.8 g in the high-energy breakfast condition. This effect of high-energy breakfast on macronutrients (an increase in energy intake from carbohydrate and a decrease in energy intake from fat and protein) in the diet was earlier documented in study in adults (Martin et al., 2000), however, in the same study it was suggested that high-energy breakfast comprising of more than 25% of total daily intake did not appear to be favourable for health as the high-carbohydrate breakfast induced an inhibition of fat oxidation throughout the day therefore suggesting that with the long-term adaptation weight gain may occur as a result of high-carbohydrate breakfast consumption. It must be taken into account that the study was in adults and the high-energy breakfast consisted of 700 kcal. In this study, high-energy breakfast consisting of ~475 kcal represented about 30% of total daily intake of the girls, however as highlighted earlier this finding may be inflated due to low daily energy intakes reported by the girls. An interesting finding was reported by Nicklas et al. (2000) in a cross-sectional study that average energy intake from breakfast in 15-year olds, among those who were breakfast consumers, was 437 kcal representing 18% of total daily energy intake. Perhaps due to underreporting of energy intake in this study high-energy breakfast exceeded the current recommendations for breakfast.

5.3 Effects of breakfast on fruit and vegetable and high-fat and sugary snack consumption

In this study, the breakfast manipulation did not affect fruit and vegetable intake of adolescent girls. The average number of fruit and vegetable consumed by the participants was only about 1 portion a day across conditions. This finding is concerning as, according to the current guidelines by NHS, 5 portions of fruit and vegetable per day is recommended. The present study disagrees with previous observational studies have reported that breakfast consumption is related to fruit and vegetable consumption (Arora et al., 2012) and that regular breakfast eaters are more likely to meet the recommendations for fruit and vegetable consumption (Utter et al., 2007); the present study implies that there is not a causative relation between breakfast and fruit and vegetable consumption.

Although the breakfast manipulation did not affect high-fat and sugary snack consumption in the present study, there was a slight reduction in number of snacks consumed - from 2.8 portions in the control and no breakfast conditions to 2.3 portions in high-energy breakfast condition, but this difference was not significance. Cross-sectional research has shown that increased snacking is associated with breakfast skipping in several studies, suggesting that those who do not eat breakfast daily consume more energy from unhealthy snacks, such as crisps and sweets, and are more likely to skip meals (lunch or dinner) than those who consume breakfast on daily basis (Dubois et al., 2007, Sjöberg et al., 2003, Utter et al., 2007). The findings from the present study suggest that the previously reported link between breakfast and snack intakes may be causal, in that the high-energy breakfast did cause a slight, but not significant, reduction in high-fat and sugary snack consumption. However, the outcomes concerning snacking in the present study cannot be directly compared with previous studies. For instance Dubois et al. (2007) examined how much of carbohydrate, fat and protein (in grams and as percentage of total daily intake) was consumed by children during meals (breakfast, lunch and dinner) and from snacks (morning, afternoon and dinner snacks), and Sjöberg et al. (2003) examined food groups such as sweets, potato crisps, soft drinks measured in grams. In the present study, the total number of snack was counted regardless of its size, and unlike in the study by Dubois et al. (2007), regardless the time of the day it was consumed. Furthermore, the definition of breakfast consumers and breakfast skippers varied across the studies being discussed.

5.4 Breakfast and its effects on physical activity

The present study appears to be the first to investigate experimentally the effects of consuming breakfast on free-living physical activity in adolescent girls, reporting that breakfast consumption compared with omission did not affect time spent in sedentary, light, moderate and vigorous activity in overweight and non-overweight adolescent girls.

Until now, only cross-sectional research has examined associations between breakfast consumption and physical activity in young people. The present study supports the findings of Lyerly et al. (2013) and Utter et al. (2007) who reported that physical activity was not related to breakfast consumption in children and adolescents. Nonetheless, an association between regular breakfast consumption and increased physical activity among children and adolescents has been previously documented by some observational studies (Arora et al., 2012, Sandercock et al., 2010, Timlin et al., 2008). In previous cross-sectional work by Corder et al. (2011), it was found that girls who consumed breakfast occasionally had lower physical activity levels in the morning compared with daily breakfast consumers (between 06.00 and 12.00). However, it is less clear whether the differences were in light activities, and whether the girls who were occasional breakfast eaters spent more time in sedentary than those who were regular breakfast eaters. Later in 2014, Corder et al. conducted a study in more depth investigating associations between breakfast consumption and physical activity by looking at the hourly patterns of MVPA in girls and boys. They found that both girls and boys who were consistent breakfast consumers did more MVPA, particularly in the morning but only at weekends, not weekdays. The peak time of MVPA was 12.00 in girls and 11.00 in boys and differed significantly between regular breakfast consumers and breakfast skippers. In the present study, physical activity levels were assessed only over three consecutive school days. This may be a potential explanation accouting for differences between results of this study and those of Corder et al. (2014). Indeed, activity levels were not assessed during the weekend in the present study and it is likely that on a school day the participants did not have an opportunity to perform physical activity at their own will during each three-day condition due to lessons. Moreover, it was previously found that adolescents have different physical activity patterns on weekend compared with weekday (Trost et al., 2000). Therefore, the three days during weekdays of physical activity monitored in this study may not have represented typical weekly physical activity of the participants. Contrary to the findings of Corder et al. (2014), Vissers et al. (2013) found, that physical activity was increased in boys compared with girls, and boys on the day when they had breakfast did more MVPA on weekday afternoons and evenings and spent less time in sedentary during mornings than non-breakfast consumers. The discrepancies in gender and physical activity require further research to examine the interplay between breakfast and physical activity among children and adolescents and highlight the importance of distinguishing between boys and girls. In addition, although these studies offered a closer look at the physical activity patters of young people, none of them examined light-intensity activities.

Cross-sectional findings have often implied that consuming compared with omitting breakfast can cause young people to be more physically active. However, the present study does not confirm that the associations between breakfast and physical activity previously documented in observational studies have a causal component. Similar results were reported in adults (Halsey et al., 2011), showing that one week of breakfast consumption or one week of fasting until mid-day did not affect energy expenditure in males and females. However, in contrast to our findings, a recent six-week intervention in lean adults documented that participants in the breakfast group engaged significantly more in light-intensity activities during the morning than did participants in the fasting group (Betts et al., 2014). The suggested reason by the authors for light-intensity activities rather than MVPA was that may be breakfast affects spontaneous behaviours contrary to conscious decisions to participate in structured physical activities or exercise. In the present study light activity levels did not differ between conditions. However, a 3-day intervention may not have been long enough to induce such changes in physical activity levels, and accelerometry used in the present study may not have provided necessary sensitivity to detect such subtle and temporal alterations in physical activities (Betts et al., 2014). Therefore, further research examining the effects of breakfast consumption and omission on physical activity in adolescent girls using one-week, rather than three-day, conditions is warranted. It was not, however, possible to implement a ‘no breakfast’ condition for one week in the present study due to ethical issues associated with asking young people to omit breakfast for this amount of time; ethical restrictions are likely to place limitations on future experimental studies seeking to explore the effects of breakfast consumption and omission in young people.

A strength of the present study was the objective measurement of physical activity using a wrist-worn accelerometer. Indeed, the majority of the previous studies relied on self-reported physical activity questionnaire (Lyerly et al., 2013, Sandercock et al., 2010), and some studies which used pedometry or accelerometry to assess physical activity (Corder et al., 2014, Pearson et al., 2009) only examined moderate-to-vigorous physical activity (MVPA) levels but not sedentary behaviour and light physical activity. In this study sedentary, light, moderate and vigorous physical activity levels were examined. Accelerometry has been previously used in some studies (Pearson et al., 2009, Vissers et al., 2013). Also GENEA wrist accelerometers, as used in the present study, have been found to produce as accurate results as hip-worn accelerometers to assess children's physical activity (Phillips et al., 2012). However, it is worth noting the irrefutable limitation concerning physical activity assessment in the present study.

5.5 Limitations of the study

The present study had several limitations. First, although the sample size of the present study was similar to previous research (for instance, 21 in study by Kral et al., 2010), including a larger sample size would have increased the likelihood of detecting statistical differences between conditions. Indeed, 33 girls took part in the study, but the data from only 24 girls were included in the final analysis.

Regarding dietary assessment, despite the benefits of the food diaries such as giving a better representation of habitual diet of the participants and more accurate information on energy intake than other dietary methods – 24-hour recall and food frequency questionnaire for instance, some research has documented a significant underestimation of energy intake when using food diaries as an assessment of energy intake (Burrows et al., 2010). This might partially explain the low energy intake values reported by the participants in the present study. Keeping a food diary can also result in alteration of habitual diet by eating or recording certain food for the ease of completion (Vissers et al., 2013). Small et al. (2009) suggested that addition of photographs may not only improve reliability of recorded food intake but also enhance the engagement in the activity itself. Although the incorporation of photograph may have improved the validity and reliability of our dietary data, it was apparent that not all the girls took photographs of all the foods and drink they consumed. For missing photographs, it is possible that dietary intake could have been over- or underestimated. In addition, energy intake of the girls was only analysed for three different time periods and excluding breakfast (from 09:00 onwards), whereas snack and fruit and vegetable consumption was assessed across the entire day only. It could be that eating and/or consumption of high-fat and sugary snack occurred around certain times, for example, in no breakfast condition increased snack intake in the morning (immediately after the breakfast club). However such behaviours were not examined in the present study.

In addition, this study was conducted in free-living conditions. During the no breakfast condition the participants were required to abstain from all foods and drinks except from water until 09.00. On the previous day before trial, the participants were encouraged to refrain from eating and drinking; however, it was not possible to take measures (e.g. fasting blood glucose) to confirm that all participants followed this instruction. Moreover, in the present study energy intake was assessed over three weekdays, whereas previous evidence suggests that food habits differ between a weekday and a weekend (Rampersaud et al., 2005).

Unlike previous studies (e.g., Betts et al. 2014), the composition of the breakfast meal was fixed for all participants to minimise between-participant variability. Although providing an absolute amount of breakfast (475 kcal) to all participants is consistent with previous research (e.g. Kral et al, 2010; Levitsky and Paconowski, 2013) and enables direct relations to nutritional recommendations, This would have meant that the heavier girls would have consumed fewer kcal per kg of body mass and possibility results in between-participant variability. Therefore, prescribing breakfast relative to body mass may have been more appropriate, particularly when comparing between overweight and non-overweight girls.
Another limitation of the study was that the breakfast intervention took place in the school setting prior to first lesson, therefore leaving the participants with limited opportunity to engage in free-living physical activity in the morning. Providing the breakfast in the school setting allowed for controlling the breakfast intervention (all girls were given exact same amount of breakfast and any leftovers were noted down by the research team), and obtaining accurate outcome measures (food diaries were checked for completeness by the research team each morning). However, there is some evidence that increased physical activity (Betts et al., 2014) and diminished time spent sedentary (Vissers et al., 2013) after breakfast consumption occurs particularly in the morning. In this study, the girls went to their lessons immediately after the breakfast club meaning that they were unable to undertake physical activity due to minimal time between the breakfast club and first lesson. Furthermore, some of the girls had an activity class (hockey) before breakfast club, and that data were not included in the analysis as only data after breakfast intervention (09:00 onwards) were examined. A suggestion for the future research would be to perhaps provide the breakfast prior to school at participants' homes; however it would be difficult to control the breakfast intervention, confirm the accuracy of food diary records, and to monitor compliance with the intervention.

Concerning physical activity assessment in the present study, although accelerometry provides an objective measurement of physical activity (Sirard et al., 2001), previous research has suggested that seven days including a weekend of activity monitoring provides a reliable estimate of usual physical activity of children and adolescents (Trost et al., 2000). Moreover, while the wrist-worn device (GENEActiv) has been found to produce valid physical activity data and improve the compliance due to convenient location where it is placed on the body (wrist-worn) (Schaefer et al., 2013), it is possible that the participants had to remove accelerometers for certain activities such as martial arts, gymnastics, dance etc., for safety or aesthetic reasons which was not examined in this study. This could partly explain the lower (approximately 50 minutes on average per day) than recommended at least 60 minutes of moderately intensive physical activity for children and young people (HSE, 2013). Also the age of the participants varied from 12 to 15 years in this study. Earlier research on physical activity indicates that younger adolescents are more physically active than older adolescents (Pearson et al., 2009); therefore, variability in physical activity levels between participants could have affected the results of the present study.

5.6 Recommendations for future research

The findings of the present study indicate a number of new potential avenues for future research that, if addressed, will broaden our understanding of the effects of breakfast consumption and omission on subsequent energy intake, eating patterns and physical activity in young people.

Firstly, it would be worth studying this topic in on a larger scale with a larger sample size. Energy intake was reduced, although not significantly, in the late afternoon/evening during high-energy breakfast condition. The effect size for measured energy intake after 14.00 until bedtime was medium (Cohen’s $r = 0.31$), therefore a larger sample size would increase the power for the statistical analyses. Although previous studies documented that breakfast skipping is more common among girls than boys, the association between breakfast skipping and unhealthy behaviours such as reduced physical activity in girls may be not as strong as reported in other studies (Rampersaud et al., 2005, Sjöberg et al., 2003) because some research reported that girls, but not boys, who regularly consumed breakfast had greater physical activity levels than those who skipped breakfast (Corder et al., 2011). Nevertheless, others have shown that both girls and boys who consumed breakfast regularly performed more physical activity compared with breakfast skippers (Corder et al., 2014). Therefore, breakfast consumption and behaviours associated with it should be examined in both sexes.

Secondly, this study examined short-term effects of breakfast on energy intake and physical activity, with each condition lasting for three days. Longer-term trials are needed to examine whether breakfast skipping causes changes in subsequent energy intake and eating patterns, such as increased energy intake in the evening and snacking, which could predispose excessive weight gain in the long-term. Another important factor of maintaining energy balance is energy expenditure. Three days of the intervention might not have been long enough to induce any changes in diet and physical activity of adolescent girls. Also, it was not possible to determine energy expenditure using accelerometry in this study, therefore further research is needed to examine the effects of breakfast on energy expenditure. Based on previous research using 7-day (rather than 3-day) assessment periods, consumption of breakfast might increase physical activity levels, especially light, unstructured activities (Betts et al., 2014). If future research succeeds to establish the link between breakfast consumption and physical activity in children and adolescents, breakfast consumption can be used as a simple means to prevent and treat obesity and health-related conditions by both enhancing dietary profiles and increasing physical activity levels in young people. Unfortunately, however, it may not be possible to study the longer term effects of breakfast consumption compared with omission in young people due to ethical issues associated with asking young people to omit breakfast over prolonged periods. On the other hand, it could be possible to compare a control breakfast trial with a high-energy breakfast trial using a seven day assessment period by examining habitual breakfast skippers.

Ultimately, longer-term trials would allow the examination of body composition and important metabolic and cardiovascular health markers such as glucose tolerance. Short-term studies, like the present study, can provide some indication as to whether breakfast consumption or omission will influence diet and physical activity and thus energy balance, which can affect obesity risk and future health. To draw firm conclusions as to whether promoting regular breakfast consumption in young people, that can improve their body composition and cardio-metabolic health, the direct measurements of health outcomes are required.

Thirdly, this research suggests that on days when high-energy breakfast was consumed, there was reduced percentage of energy intake from fat and increased percentage of energy intake from carbohydrate, as well as a slight reduction in the number of the high-fat and sugary snacks. In the future, it is worth investigating the whole nutrient profile of the participants i.e. macronutrient as well as micronutrient intake. Also, to understand better snacking behaviour, it could be necessary to investigate specific times of the day when most snacking occurs, amount of and percentage of total energy intake from unhealthy, energy-dense foods. Since there were some indications that energy intake in the afternoon-evening was reduced when participants consumed the high-energy breakfast, it may be worth examining these effects further; for example, isolating the afternoon from the evening or examining the late-evening period only.

Another consideration for the future research would be the type of breakfast provided during breakfast condition. It might be worth investigating the effects of different types of breakfast, for instance, breakfast containing low GI compared with high GI carbohydrates, on energy intake and energy expenditure. For instance, Warren et al. (2003) reported that low GI breakfast compared with high GI breakfast consumption on 3 consecutive days resulted in reduced energy intake at lunch in overweight and non-overweight children aged between 9 and 12. This study suggests that low GI diet may have an important role in weight control and obesity management, therefore investigating the long-term effects of low GI breakfast on subsequent energy intake is needed. Additionally, it would be interesting to examine perceived hunger ratings after breakfast and prior next meal, although assessing subjective ratings before next meal would be particularly burdensome in free-living conditions.

Lastly, the present work also highlights the lack of the experimental research on the interplay between breakfast, energy intake and physical activity in adolescents, which limits interpretation of the present outcomes. Previous research in adults remains inconclusive and is not applicable to younger population. Therefore, future experimental research in various populations is required to assess whether more frequent breakfast consumption results in improved body composition and health when compared with breakfast omission.

5.7 Conclusion

The findings of the present study showed that consuming a breakfast containing ~475 kcal for three days increased total daily energy intake and did not affect physical activity in overweight and non-overweight girls aged 12-15 when compared with consuming no breakfast or the participant's habitual breakfasts. The higher energy intake in the breakfast condition was due to the additional calories, mainly from carbohydrate, provided at breakfast; the girls did not make up the missing energy from breakfast during the morning-early afternoon or during late-afternoon evening during the no breakfast and control conditions. This resulted in diets comprising of a higher percentage of carbohydrate and lower percentage of fat during the high-energy breakfast condition. It may also be noteworthy that calorie consumption during the afternoon-evening and daily high- fat and sugary consumption tended to be lower in the breakfast condition. Although time spent in sedentary, light, moderate and vigorous physical activity remained similar across conditions, further research with trial and measurement periods of at least one-week in duration is required to assess these effects with a greater degree of certainty. These findings open a number of new research questions, indicating a need of experimental evidence within this area. Therefore, further research investigating the effects of breakfast on diet and physical activity in girls and boys is warranted to inform recommendations for breakfast consumption for young people.

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Appendices

Appendix 1: Invitation e-mail to school

Invitation e-mail to school

Dear ____________ (usually the Head teacher/ PE teacher/ Healthy Schools Coordinator/ Head of year)

Thank you for returning my call earlier today about the Girls Breakfast Project that we are running at the University of Bedfordshire. I hope that the information below and attached is helpful and I am looking forward to hearing from you about the school's involvement once you have spoken to your Head teacher.

Breakfast is commonly believed to be 'the most important meal of the day' and can benefit both health and academic performance in children and adolescents. The Girls Breakfast Project is the first study to examine whether consuming or 'skipping' breakfast affects total energy intake, eating patterns and physical activity throughout the day. This exciting new research project is being conducted by researchers at the University of Bedfordshire and I am e-mailing you to invite your school to participate.

_____________ School has been chosen as a representation of UK children and it would, therefore, be fantastic if you were to be involved. The age group the study is looking at is 12-15, meaning that we would like to invite girls in Year 8/ 9/ 10 (delete as appropriate) to participate.

Regarding the school's involvement in the study, we can be very flexible to minimise disruption to the everyday proceedings of the school. Briefly, we would like to visit the school for the following:

1. Presentation/talk to invite the students to participate and hand out parental consent forms.

2. To take some initial baseline measurements (e.g. height, weight, lifestyle questionnaire).

3. To implement a 'Breakfast Club' run over 3 days (e.g. Tuesday-Thursday) for three weeks. These are the main trials, which involve asking the participants to continue with their normal breakfast habits, consume no breakfast or consume a high-energy breakfast before school. After breakfast, the participants are asked to record their diet for the remainder of the day. We can also give some of the children physical activity monitors to wear.

Please do not hesitate to contact me with any questions.

I hope to hear from you soon.

Kind regards

_______________ (sign)

Appendix 2: School Information sheet

Girls' Breakfast Project

Does eating breakfast affect diet and physical activity during the remainder of the day in girls aged 12-14 years?

Breakfast is commonly cited as 'the most important meal of the day' and may benefit both health and academic performance in children and adolescents. However, researchers do not know whether routinely eating breakfast can improve diet and physical activity levels. The Girls' Breakfast Project aims to investigate the effect of consuming compared with skipping breakfast on subsequent diet (e.g. energy intake, eating patterns) and physical activity in girls aged 12-14 years. The study is run by researchers at the University of Bedfordshire and involves asking girls to eat a specific breakfast in the morning at school or 'skip' breakfast (all breakfasts will be provided by us). The participants will then be asked to record all the food and drink that they consume for the rest of the day (after 9.00am). This is the first study of its kind and the findings will be used to contribute to interventions that aim to improve the health of young people.

The following pages contain full details about the project procedures. We hope this will reassure you that involvement would not be too disruptive to school proceedings. Please also note that participants can withdraw from the study at any time or decline answers to the questionnaires without any penalty. Data will remain confidential on a password-protected computer and will be analysed by one of the study researchers.

We would ask to visit the school on the following occasions:

Visit 1: Presentation to girls in Year 8 (approx. 20 min)
We will explain the study aims and procedures so that the students are provided with enough information to decide whether they would like to volunteer. All students will receive an information sheet and parental consent form, which should be given to their parent/guardian and returned to the school within three days. Only those who return their consent form will be eligible to participate in the study.

Visit 2: Baseline measurements (approx. 1 hour)
We will ask the volunteers to complete a child assent form and lifestyle questionnaire to provide information on their normal breakfast habits. We will then take some preliminary measurements, including height and body composition.

Visits 3-11: '3-day breakfast club' ran over 3 weeks (e.g. 30 min session before school on Tuesday-Thursday for 3 consecutive weeks)
The participants will be asked to arrive at school half an hour early on three school days for a period of three weeks (e.g. every Tuesday, Wednesday and Thursday for three weeks). Each week, participants will either be asked to continue with their normal breakfast habits, consume no breakfast or consume a high-energy breakfast, as follows:

Week 1 - We will ask participants to continue with their normal morning routine and record all food and drink consumed at breakfast.

Week 2 and 3 - Participants will be asked to arrive at school having consumed no food or drink except water in the morning. We will then ask the girls to either consume no breakfast or a high-energy breakfast over each 3-day period. The breakfast consists of Weetabix with semi-skimmed milk and a glass of orange juice.

For each 3-day period (week 1, 2 and 3), after breakfast, participants will be asked to keep a food diary, detailing everything they have consumed that day. To aid the completion of the food diary, the girls will be asked to photograph food consumed throughout the day and use the photos as recall tool to complete the food diary that evening. Each morning at school, we will check the food diaries to ensure that they have been completed accurately. Thus, although the girls continue with their normal breakfast habits on week 1, we will need to meet the girls briefly at school to check their food diary for the previous day. Some participants will also be provided with a physical activity monitor to wear around their waist.

Please also note that our researchers have clearance from the Disclosure and Barring Service (DBS) and can run the study with no extra staff, although teachers or school staff are more than welcome to attend the trials. We can provide breakfast before registration each morning, so that the main trials should not impact on school time. We will, however, require a space to serve the breakfasts.

Main benefits of taking part:

- Participating in the project can **enhance the student's learning** by providing them with the opportunity to participate in a novel **scientific research** project. Students will become familiar with research procedures and grasp an understanding of reasons for conducting research.
- We can provide the school with a **summary of the research findings** and valuable information on the average daily energy intake and breakfast habits of the students who participate.
- All participants receive a **certificate** stating that they took part in the project.

If you are interested in participating in this exciting research project, please do not hesitate to contact me (contact details below) for further information and/or to arrange a meeting (note that this does not mean that the school is obliged to participate).

Yours sincerely

Julia Zakrzewski

Dr. Julia Zakrzewski
Department of Sport Science and Physical Activity
University of Bedfordshire
Polhill Avenue
Bedford
Tel: 01234 793410
Email: Julia.Zakrzewski@beds.ac.uk

Appendix 3: Parental information form

PARENTAL INFORMATION AND CONSENT FORM FOR A CHILD TO PARTICIPATE IN A RESEARCH STUDY

Girls Breakfast Project

Is breakfast really the most important meal of the day? A study examining the effect of eating and skipping breakfast on subsequent diet and physical activity in girls.

We are writing to you to invite your daughter to take part in an exciting new research project being run at Mark Rutherford School by the University of Bedfordshire. Breakfast is commonly cited as 'the most important meal of the day' and may benefit both health and academic performance in children and adolescents (young people). However, researchers do not know whether eating compared with skipping breakfast can affect diet and physical activity throughout the day. The Girls Breakfast Project aims to investigate the effect breakfast consumption and skipping on subsequent diet and physical activity in girls aged 12-15 years. This is the first study of its kind and the findings will be used to contribute to interventions that aim to improve the health of young people. We, therefore, hope as many girls as possible from those invited will take part.

This letter provides you with more detailed information about the study and what would be involved if you give permission for your child to take part. Please do not hesitate contact us if you have any further questions. If you agree to your child participating, please complete the slip at the end of the form and return it to the school. We would like to reassure you that if you sign up today, you/your child are still free to drop out at any time, without giving us a reason. If your child does not participate, there will be no disadvantage to you or your child and we thank you for considering our request.

What you should know about a research study

- We give you this consent form so that you may read about the purpose, risks and benefits of this research study.
- The main goal of research studies is to gain knowledge that may help future generations.
- You/ your child have the right to refuse to take part, or agree to take part now and change your mind later on.
- Please review this consent form carefully and ask any questions before you make a decision.
- Your child's participation is voluntary.
- By signing this consent form, you agree to your child participating in the study as it is described.

What is the aim of the project?

The aim of the study is to examine the effect of eating compared with not eating breakfast on subsequent diet (e.g. calorie intake, eating patterns) and physical activity in girls.

Who is conducting the study?

Dr. Zakrzewski directs this study with colleagues from the University of Bedfordshire. Students at the University of Bedfordshire will be visiting schools in Bedford to collect data. The research team have clearance from the Disclosure and Barring Service (DBS – formerly Criminal Records Bureau).

Who is eligible to participate in the study? Who is ineligible?

Your child is eligible for the study if:

- Your child is enrolled in a school that is participating in the study.
- Your child is aged between 12 and 15 at the time of study enrolment.
- You (the parent or legal guardian) and your child agree (by signing this form) to participate in the study.
- Your child signs the separate assent form indicating that she wishes to volunteer for the study.

Your child will not be eligible for the study if:

- You (the parent or legal guardian) do not sign this consent form, or your child does not sign the assent form indicating that they wish to volunteer.
- Your child has allergies to any of the ingredients in Weetabix, milk or orange juice (e.g. wheat, barley, dairy products, lactose).
- Your child is not prepared to eat/ drink the following for the study: Weetabix with semi-skimmed milk and a glass of orange juice (no sugar on the Weetabix).
- Your child is fitted with a Pacemaker or Other Internal Medical Devices (the body composition analyzer SC-240 sends a weak electrical current through the body during measurement).
- A General Health Screen Questionnaire must be completed for each child who volunteers to participate in the study. Children with the following conditions will be excluded from the study for their own safety: musculoskeletal injury that has affected normal movement within the last month, disturbance of vision, congenital heart disease, uncontrolled exercise-induced asthma, diabetes, epilepsy and chronic obstructive pulmonary disease (COPD). As it is not feasible to list every medical condition, it is possible that children with other medical conditions, not given above, may be excluded from the study once identified.

What will participants be asked to do?

You (the parent or legal guardian) will be asked to complete this consent form and provide us with contact details so that we may call you during the period that your child is partaking in the study to see whether you have any questions. During the first visit to the school, we will ask the volunteers to complete a child assent form and lifestyle questionnaire to provide information on their normal breakfast habits. We will also take the following measurements: height, weight and body composition (the percentage of body fat, muscles and bone).

The remainder of the visits will take the form of a 3-day ‘breakfast club’ at school. The participants will be asked to arrive at school half an hour early on three school days for a period of three weeks (e.g. every Tuesday, Wednesday and Thursday for three weeks). Participants will either be asked to continue with their normal breakfast habits, consume no breakfast or consume a high-energy breakfast, as follows:

Week 1 - We will ask participants to continue with their normal morning routine and record all food and drink consumed at breakfast.

Week 2 and 3 - Participants will be asked to arrive at school having consumed no food or drink except water in the morning. We will then ask the girls to either consume a glass of water (no breakfast) or a high-energy breakfast for each 3-day period. The breakfast consists of Weetabix with semi-skimmed milk and a glass of orange juice. Each week, the participants will be assigned to a different condition. Therefore, please note that participants will be asked to consume no breakfast for one of the 3-day periods. Potentially, this could lead to some participants feeling light-headed, but this is very rare and all participants are free to eat or drink as they please for the remainder of each day (from 9:00am).

For each 3-day period (week 1, 2 and 3), following breakfast, participants will be asked to take photos of the food and drink that they consume for the rest of that day. The photos can be used to help complete their food diary at the end of the day; this is a booklet detailing everything they have consumed, including all meals and snacks. Our researchers will provide additional help in completing the food diary the following morning at breakfast club. Some of the participants will also be given a physical activity monitor (an ‘accelerometer’) to wear around their waist during the trials to provide an indication of whether consuming breakfast leads to higher activity levels.

Taking the children’s measurements will be coordinated with school administrators so as to not conflict with important school activities or tests. All measurements will be confidential and will not be shown to anyone other than researchers involved in the study. School teachers and other staff will not be allowed to see your child’s measurements. The display for weight and body fat is covered so that it is not visible to any person (these results are transferred and stored on a computer).

What are the possible risks of taking part in the study?
This is a minimal risk study and the health of your child will be the researcher’s first consideration; a researcher shall act in your child’s best interest throughout the study period. All girls who volunteer to participate will be asked to consume a breakfast containing Weetabix with semi-skimmed milk (no sugar!) and orange juice. If your child is allergic to any of these ingredients, they cannot participate in the study. All participants will be required to skip breakfast on 3 consecutive days for the purposes of the study (they will only be provided with a glass of water at breakfast club), but will be free to eat or drink as they chose after 9:00am. This is a very important part of the research and will allow us to look at whether skipping breakfast affects lifestyle and behaviour. Finally, please be aware that all children participating in the study will miss approximately 1 hour of school time, which has been approved by the Head teacher.

What are the possible benefits?
This is an exciting opportunity for your child to be involved in a novel and relevant research study, which will produce important findings for improving the health of young people. Participating in the project can enhance your child’s learning; the participants will become familiar with research procedures and grasp an understanding of reasons for conducting research. We can provide the school with a summary of the research findings and valuable information on the daily energy intake levels and breakfast

habits of the students who participate. All students who participate receive a signed certificate stating that they took part in the project.

What if your child decides to withdraw from the project?
Your child is free to withdraw from the study at any time and without giving a reason. There will be no disadvantage to your child if she should you wish to withdraw.

What will happen to the data and information collected?
All information and results collected will be held securely at the University of Bedfordshire and will only be accessible to related University staff. Results of this project may be published, but any data included will in no way be linked to any specific participant. Your child's anonymity will be preserved. All data will be collected in a confidential manner. Your child will be given a unique identity number and names will not appear on questionnaires or data collection forms.

What charges will you be asked to pay or will you receive?
None.

What if you have any questions?
Questions are always welcome and you should feel free to ask Dr. Julia Zakrzewski or Tatiana Plekhanova any questions at anytime. Contact details are as follows:

Dr. Julia Zakrzewski - Julia.Zakrzewski@study.beds.ac.uk/ 01234 793410
Tatiana Plekhanova - Tatiana.Plekhanova@study.beds.ac.uk

This project has been reviewed and approved by the Ethics Committee of the Department of Sport Science and Physical Activity.

Yours sincerely,

Dr. Julia Zakrzewski
Department of Sport and Exercise Sciences,
University of Bedfordshire
Bedford Campus,
Polhill Avenue,
Bedford
Tel: 01234 793410
Email: Julia:Zakrzewski@study.beds.ac.uk

Appendix 4: Parental consent form

PARENTAL INFORMED CONSENT FORM

Girls Breakfast Project: studying the effect of breakfast energy intake on subsequent diet and physical activity in adolescent girls

Thank you for your interest in the Girls Breakfast Project. Please provide your signature below to confirm that the study has been explained to you and all your questions have been answered. If there is anything you do not understand, you are aware that you can ask anyone from the study team using the contact details provided.

The study volunteer is a child and I certify that I am his/her legal guardian.

Name of Child: ________________________________

Date of Birth: _____ /_____ /_________ **Age:** __________

Name of parent (or guardian): ____

Relationship to child: _______________________

Address: ____

Postcode: __________________

Contact telephone number: _______________________ **(home)**

_______________________ **(work)**

_______________________ **(mobile)**

e-mail address: ____________________

____________________________________ _____/_____/______

Parent (or legal guardian) signature **Date**

Appendix 5: Child assent form

ASSENT TO BE IN A STUDY

Girls Breakfast Project: studying the effect of breakfast energy intake on subsequent diet and physical activity in adolescent girls

Name of Principal Investigator: Dr. Julia Zakrzewski
Contact: Julia.Zakrzewski@beds.ac.uk

Why am I here?

The study team are interested in whether breakfast is related to diet and physical activity and want to see if I would like to be in this study.

Why are they doing this study?

They want to learn more about relationships between breakfast and daily diet and physical activity in young people aged of 12 – 15 years.

What will I be asked to do if I take part?

1. I will have some baseline measurements taken, including height and weight.
2. I will come into school for the main trials for 3 days each week over three weeks. On one of these 3-day periods, I will have consumed my normal breakfast each day. On another two periods, I will either consume a glass of water for breakfast or Weetabix with milk and orange juice.
3. During each 3-day period, I will take photos of the food and drink I have, fill out a food diary and write down how much food I eat throughout the day. I may also be asked to wear a physical activity monitor around my waist.

What if I have any questions?

I can ask questions any time. I can ask now. I can ask later. I can talk to the study team or I can talk to someone else.

Are there any reasons that I cannot take part in the study?

You can take part in the study if:

- You are a pupil in a school that is participating in the study.
- You are in aged 12 - 15 at the time the study is being carried out.
- Your parent (or legal guardian) agrees (by signing the parental consent form) that you can participate in the study.
- You sign this form showing that you wish to volunteer for the study.

You will not be able to take part in the study if:

- Your parent or legal guardian does not sign the consent form, or if you do not sign this form showing that you wish to volunteer for the study.
- You have any health-related issue that could be affected by the study, e.g. allergies to the breakfast foods that will be used in the study (Weetabix, milk, orange juice).
- You are unable to walk or wear physical activity monitor on your waist.
- You are fitted with a Pacemaker or other internal medical devices (one of our pieces of equipment sends weak electrical current through the body in order to detect measurements and could put those with pacemakers or other internal medical devices at risk).

Do I have to be in the study?

I don't have to be in this study. No one will be mad at me if I don't want to do this. If I don't want to be in the study, I just have to tell the study team. If I want to be in the study, I just have to tell the study team. I can say yes now and change my mind later. It is up to me.

I understand that data will remain confidential on a password secure computer and that it will be looked at by one of the team members. I understand that my health will be the researcher's first consideration and a researcher shall act in my best interest throughout the study period.

I have read the Participant Information Sheet concerning this project and understand what it is about. All my further questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

______________________________ _______________ _________________

Name of Volunteer Date of birth Date

____

Signature of Person Administering Informed Consent Date

Appendix 6: Lifestyle questionnaire

For official use only. QUALITY CONTROL (QC) and DATA ENTRY: QC Staff Initials: ____________________________ Date: ______ / ________ / _______
Data Entry Staff Initials: ______________________ Date: ______ /________ / _______ Page **1** of **3**
PID: _____________ Technician Initials: ___________ Date: ____________

Lifestyle Questionnaire

Please read every question carefully. Choose the box that fits your answer best and fill it in. This is not a test so there are no wrong answers. Also, nobody who knows you will look at your questionnaire once you have finished it.

1. How often do you usually have **breakfast**? Mark one box for weekdays and one box for weekend.

Weekdays Weekend

I never have breakfast on weekdays I never have breakfast on the weekend
One day I usually have breakfast on only one day of
Two days the weekend (Saturday OR Sunday)
Three days I usually have breakfast on both weekend
Four days days (Saturday AND Sunday)
Five days

2. Where do you normally consume breakfast? Mark one box for weekdays and one box for weekend.

Weekdays Weekend

At home At home
On way to work/school/University On way to work/ school/University
Other: _________ Other: __________

3. What do you normally eat and drink for breakfast?

Weekdays (Monday to Friday): ____

Weekends (Saturday and Sunday): ____

4. What time do you normally consume breakfast?

Weekdays:

□□:□□ AM / PM (circle AM or PM)

Weekend days:

□□:□□ AM / PM (circle AM or PM) **For official use only.**

QUALITY CONTROL (QC) and DATA ENTRY:
QC Staff Initials: ____________________________ Date: ______ / ________ / _______
Data Entry Staff Initials: ______________________ Date: ______ /________ / _______
Page **2** of **3**
PID: _____________ Technician Initials: ___________ Date: ____________

5. On a weekday, how many hours did you watch TV?

I did not watch < 1 hour 1 hour 2 hours 3 hours 4 hours 5 or more hours
TV on week
days
6. On a weekday, how many hours did you play video or computer games or use a computer for something that was not work?

I did not play < 1 hour 1 hour 2 hours 3 hours 4 hours 5 or more hours
video/computer
games or use a
computer other
than for work on week days
7. On a weekend day, how many hours did you watch TV?

I did not watch < 1 hour 1 hour 2 hours 3 hours 4 hours 5 or more hours
TV on weekend
days
8. On a weekend day, how many hours did you play video or computer games or use a computer for something that was not work?

I did not play < 1 hour 1 hour 2 hours 3 hours 4 hours 5 or more hours
video/computer
games or use a
computer other
than for work on the weekend
9. In the last week you were in work, the **MAIN** part of your journey to school was by:

☐ walking

☐ bicycle, roller-blade, skateboard or scooter

☐ bus, train, tram, underground or boat

☐ car, motorcycle or moped

☐ other

For official use only. QUALITY CONTROL (QC) and DATA ENTRY:
QC Staff Initials: ____________________________ Date: ______ / ________ / _______
Data Entry Staff Initials: ______________________ Date: ______ /________ / _______

PID: _____________ **Technician Initials:** ___________ **Date:** ____________

10. In the last week you were in school, **HOW LONG** did it take you to travel to work?

< 5 minutes 5 - 15 minutes 16 - 30 minutes 31 minutes to 1 hour >1 hour

11. During the past week (7 days), on how many days were you physically active for a total of at least 30 minutes per day? (all the time you spent in activities that increased your heart rate and made you breathe hard)

0 days 1 day 2 days 3 days 4 days 5 days 6 days 7 days

12. During the past week, what time have you usually turned out the light and gone to sleep on week days?

☐☐:☐☐ AM / PM (circle AM or PM)

13. During the past week, at what time have you usually woken up in the morning on week days**?**

☐☐:☐☐ AM / PM (circle AM or PM)

14. During the past week, what time have you usually turned out the light and gone to sleep on weekend days?

☐☐:☐☐ AM / PM (circle AM or PM)

15. During the past week, at what time have you usually woken up in the morning on weekend days?

☐☐:☐☐ AM / PM (circle AM or PM)

16. During the past week, how would you rate your sleep **quality** overall (how **well** you sleep)?
very good fairly good fairly bad very bad

17. During the past week, how would you rate your sleep **quantity** overall (how **much** you sleep)?
very good fairly good fairly bad very bad

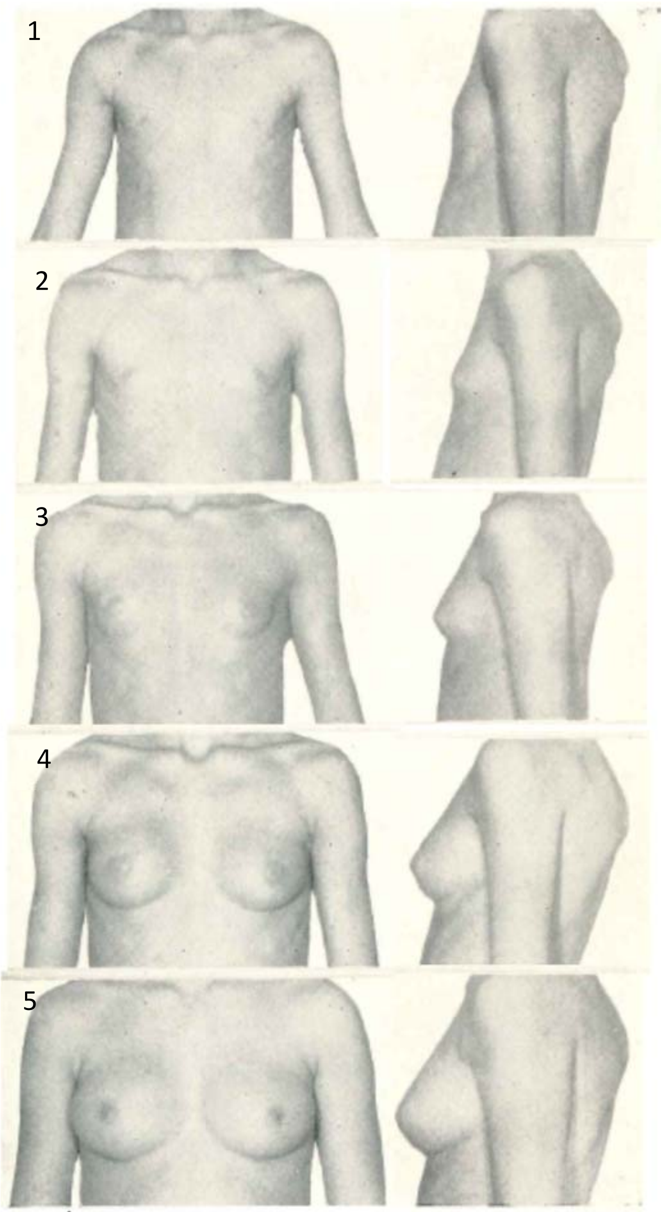
18. Do you have a television in your bedroom?
Yes No

Thank you

Appendix 7: Tanner maturation questionnaire

1. BREAST DEVELOPMENT (MATURITY RATINGS)

The pictures on this page show the different stages of development of the <u>female breast</u>. A girl passes through each of the five stages shown by these pictures. Please look at each of the pictures and read the sentences alongside the pictures. Then choose the picture closest to your stage of development and circle the corresponding number (1-5) on the enclosed confidential form.



Stage 1
The nipple is raised a little in this stage. The rest of the breast is still flat.

Stage 2
This is the breast bud stage. In this stage, the nipple is raised more than in stage 1. The breast is a small round. The areola (coloured skin around the nipple) is larger than in stage 1.

Stage 3
The areola and the breast are both larger than in stage 2. The areola does not stick out away from the breast.

Stage 4
The areola and the nipple make up a round that sticks up above the shape of the breast. This stage may not happen at all for some girls, some girls will develop from stage 3 to stage 5 with no stage 4.

Stage 5
This is the mature adult stage. The breasts are fully developed, only the nipple sticks out in this stage. The areola has moved back to the general shape of the breast

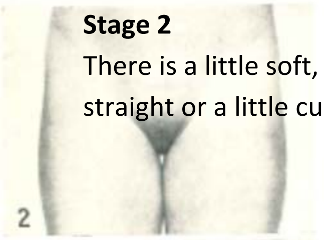
It is very important that you try to be as accurate as you possibly can when completing this self-assessment. We are not interested in who is the most or the least physically mature in our study. With a range of girls involved in the study, it is perfectly normal to find that values differ between individuals; in fact, we would be very surprised to find that everyone is the same. You can be 100% confident that whatever values you write on your response form, they will never be available to anyone not involved in the study.

2. PUBIC HAIR DEVELOPMENT (MATURITY RATINGS)

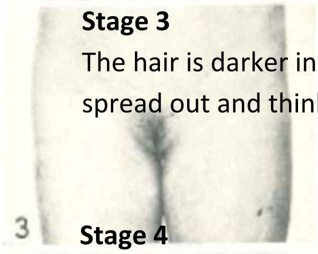
The pictures on this page show different amounts of <u>female pubic hair</u>. A girl passes through each of the five stages shown by these drawings. Please look at each of the pictures and read the sentences alongside the pictures. Then choose the picture closest to your stage of development and circle the corresponding number (1-5) on the enclosed confidential form.

Stage 1
(No picture)

Stage 1
There is no pubic hair at all.

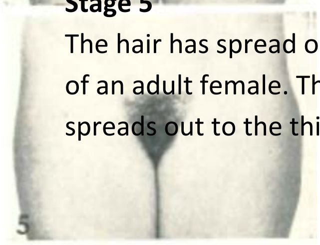


Stage 2
There is a little soft, long, lightly coloured hair. This hair may be straight or a little curly.



Stage 3
The hair is darker in this stage. It is coarser and more curled. It has spread out and thinly covers a larger area.

Stage 4
The hair is now as dark, curly, and coarse as that of an adult female. However, the area that the hair covers is not as large as that of an adult female. The hair has not spread out to the thighs.



Stage 5
The hair has spread out to touch the thighs. The hair is now like that of an adult female. The hair usually forms a triangle pattern (▼) as it spreads out to the thighs.

It is very important that you try to be as accurate as you possibly can when completing this self-assessment. We are not interested in who is the most or the least physically mature in our study. With a range of girls involved in the study, it is perfectly normal to find that values differ between individuals; in fact, we would be very surprised to find that everyone is the same. You can be 100% confident that whatever values you write on your response form, they will never be available to anyone not involved in the study.

Appendix 8: Food diary

FOOD DIARY

We would like you to record everything you eat and drink in this food diary. Please see the following instructions on how to complete the food diary:

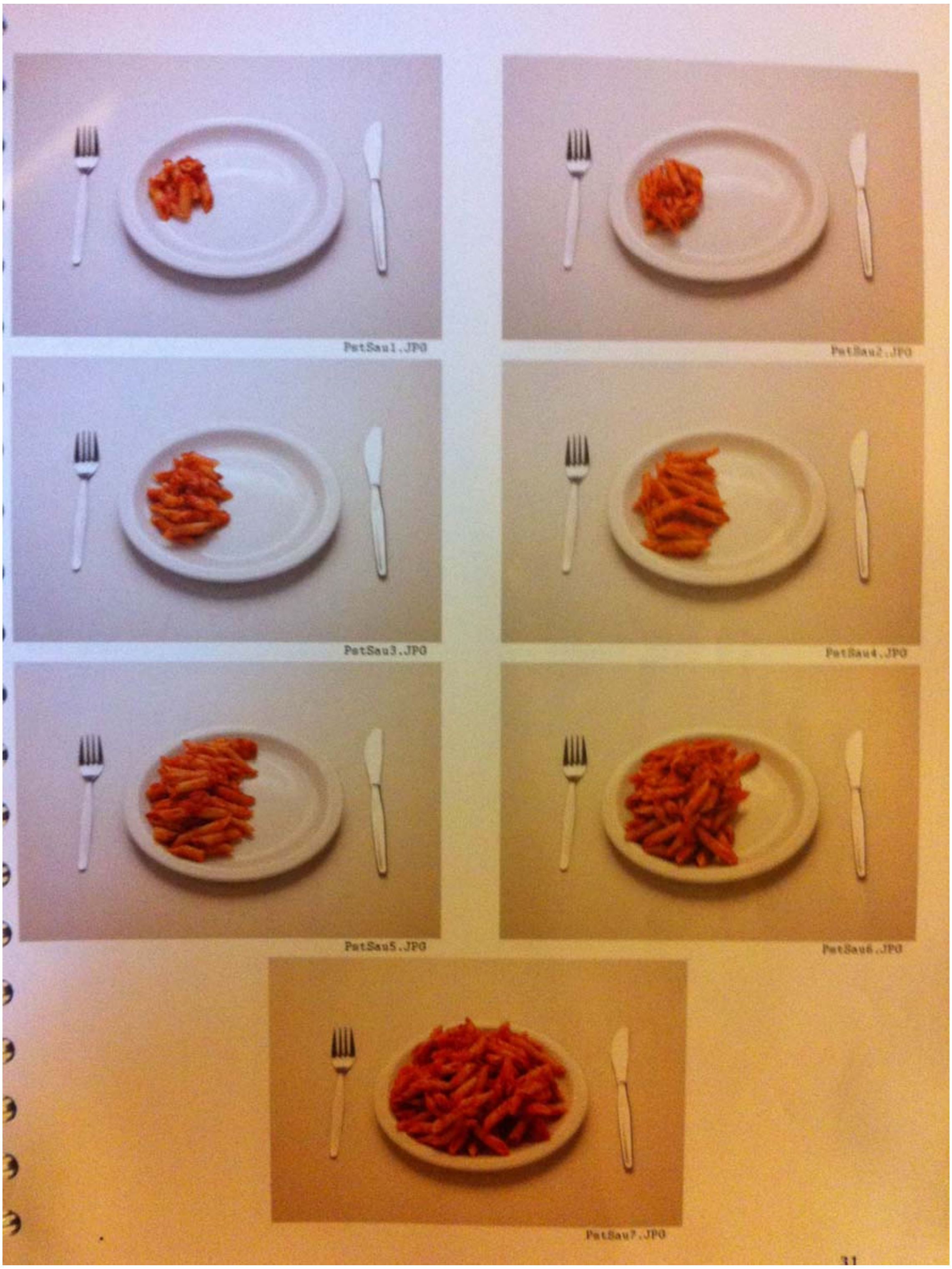
- **Everything** that you eat and drink over the course of the testing should be recorded in this diary.
- **Leftovers** (e.g. Apple cores, crusts of bread) should also be recorded indicating how much was left.
- **Eating out**—most people eat foods away from the home each day; please do not forget to record these. If you do not have the diary on you at the time of eating or drinking please take a picture on the digital camera provided so that you can fill in the diary when convenient.
- Most snack foods will have the weight of the food on the packet so they do not need to be weighed if you eat the whole item (e.g. full packet of crisps)

We understand that accurately recording your food and drink take times and effort and there may be a time where it is difficult to record and food and drink consumed. However, please avoid missing things out or making it up! This information is important for understanding our results from the study. Thank you!

Participant Number: ___________________

Time of day	Brand name (e.g. Heinz, Tesco, Kellogs)	Detailed description of food/drink and cooking method (e.g. boiled potatoes, canned sweetcorn, bacon fried in sunflower oil)	Weight served (grams)	Did you leave any? Weight of leftovers? (grams)

Appendix 9: An example from a Young Person's Food Atlas (Foster et al., 2010)


PstSau1.JPG
PstSau2.JPG
PstSau3.JPG
PstSau4.JPG
PstSau5.JPG
PstSau6.JPG
PstSau7.JPG