THE RELATIONSHIP BETWEEN APPETITIVE TRAITS, DIETARY INTAKE AND WEIGHT GAIN IN THE GEMINI COHORT

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A thesis submitted for the degree of Doctor of Behavioural Nutrition

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DECLARATION

I, Hayley Syrad confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the text and acknowledgements.

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ABSTRACT

This thesis uses data from the Gemini twin birth cohort to explore interrelationships between appetite, dietary intake, consumption patterns and weight during early childhood. Specifically it aims to: (i) describe the dietary intake of young children; (ii) explore associations between appetite, eating patterns, and dietary intake; (iii) identify associations between eating patterns and weight gain; (iv) examine the mediation of the appetite-weight relationship by eating patterns; and (v) assess the continuity and stability of appetite and eating patterns from early to middle childhood.

Chapter 4 describes the dietary intake of children aged 21 months in relation to UK public health nutrition recommendations. At a population level, young children are exceeding recommended intakes of energy and protein but not meeting recommended intakes of Vitamin D or iron. **Chapter 5** explored the role of appetite in dietary intake during the complementary feeding period. Children with lower appetitive avidity consumed more milk, and had lower food intake, than those with more avid appetites. Mothers reported supplementing their child's diet with formula milk due to 'picky' eating.

Chapter 6 explored the role of appetite in *how* children eat and drink. Food Responsiveness was associated with higher 'meal frequency', and Satiety Responsiveness was associated with larger 'meal size'. **Chapter 7** established that larger meals, but not more frequent eating, were associated with weight status at aged two, and weight gain from two to five years. These associations were replicated cross-sectionally in a nationally representative sample. **Chapter 8** demonstrated that meal size partially mediated the relationship between Satiety Responsiveness and weight. Findings from **Chapter 9** suggested that appetite and eating patterns track moderately from early to mid-childhood.

Overall this thesis identifies behavioural pathways through which individual differences in appetite may result in weight gain.

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CHAPTER 1. APPETITE, DIETARY INTAKE AND OVERWEIGHT IN EARLY LIFE: A REVIEW OF THE LITERATURE

1.1 Weight gain in early life

The prevalence of overweight and obesity in developed countries for children and adolescents (<20 years) is estimated to have risen from 16.9% of boys and 16.2% of girls in 1980 to 23.8% of boys and 22.6% of girls in 2013 (Ng et al. 2014). It does appear that the prevalence of childhood overweight is beginning to plateau in a number of countries, including England (Olds et al. 2011), but nevertheless excess weight in children is a worldwide problem. Data from the UK National Child Measurement Programme (NCMP) show that one in five children are overweight or obese when they start primary school (aged four to five years), and the proportion rises to one in three children aged 10-11 years at the end of primary school (Public Health England 2016).

Weight gain during infancy has been shown to predict overweight and obesity in later childhood (Baird et al. 2005; Druet et al. 2012). A systematic review of 24 studies exploring associations between infant size during the first two years of life and subsequent obesity observed that most studies showed that obese infants, or those at the highest end of the distribution for weight, were at increased risk of obesity. In addition, infants who grew more rapidly were at increased risk for later obesity (Baird et al. 2005). A meta-analysis of 10 cohort studies from the UK, France, Finland, Sweden, the US and Seychelles containing individual-level data on 47661 participants explored the associations between infant weight gain and subsequent obesity using weight standard deviation scores (SDS). Weight SDS are used to determine whether a child is growing at a faster or slower rate than the population mean. Children's weights are referenced against the population mean in 1990, for the child’s exact age at the time of measurement, sex, and gestational age (Cole et al. 1995). The meta-analyses found that each additional one unit increase in weight SDS between birth and one year of age was associated with a twofold higher risk of childhood obesity, and a 23% higher risk of adult obesity, adjusted for sex, age and birth weight (Druet et al. 2012). These studies highlight the importance of identifying factors that influence growth trajectories early in life.

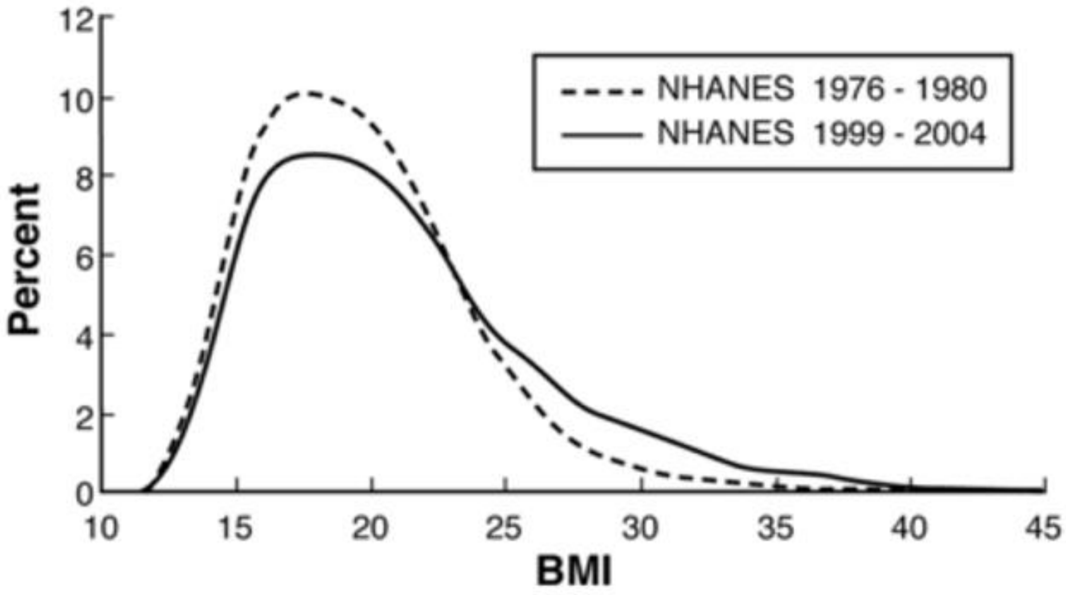
Excess weight in childhood also tracks into adulthood (Singh et al. 2008), with obese children and adolescents approximately five times more likely to be obese in adulthood than those who are not obese (Simmonds et al. 2016). Obesity carries many long-term health effects including premature mortality and physical morbidity in adulthood (Reilly & Kelly 2011). Excess weight in children can also lead to adverse psychological effects such as depression (Rawana et al. 2010), and overweight children are more likely to be bullied than their healthy weight peers (Janssen et al. 2004). In addition to the personal costs of excess weight, there are huge economic costs to society. Obesity and obesity-related conditions cost the UK National Health Service over £5 billion per year (Scarborough et al. 2011). Understanding the underlying causes of excess weight is important in order to develop evidence-based interventions which target the prevention of overweight in children.

1.1.1. Risk factors for childhood obesity

Weight gain occurs when energy intake exceeds energy expenditure. However it is widely acknowledged to be influenced by a combination of complex genetic and environmental factors (Vandenbroeck et al. 2007). The current thesis focuses on individual psychology (appetitive traits which may drive eating behaviour) and food consumption (the quality, quantity and frequency of the diet).

Heritability estimates of weight are approximately 70% for children, ranging from 41% to 90% across studies (Silventoinen et al. 2010; Silventoinen 2016); and 28-67% for infants (Johnson et al. 2011; Mook-kanamori et al. 2012; Llewellyn et al. 2012; Silventoinen et al. 2010). However, while genes account for much of the variation in weight among the population at any one time, changes to the environment are believed to have caused the large increases in weight that have occurred over the course of the obesity epidemic. That is, the rapid increase in rates of overweight in children over the past 30 years are thought to have been influenced by exposure to an obesity promoting environment (Swinburn et al., 2009). George Bray put it very well when he said: “Genes load the gun, the environment pulls the trigger” (Bray 1996).The term ‘obesogenic’ is often used to describe an environment in which food is highly palatable, energy dense, accessible, served in large portions, heavily marketed and relatively cheap (Swinburn et al., 2011). Modern ‘everyday life’ also requires very little physical exertion with multiple technological advances such as mechanised transport reducing energy expenditure, and televisions and computers promoting sedentary time (Brownson et al. 2005). However, not everyone has gained weight in response to the changing environment. In fact, increases in weight and Body Mass Index (BMI) have been greatest at the higher end of the weight distribution (Ogden et al. 2007; Wardle & Boniface 2008), as shown in **Figure 1.1**. This suggests there might be gene-environment interactions in the determination of weight; i.e. some individuals may be responding more strongly to the 'obesogenic' environment than others, and are more susceptible to becoming obese. Understanding the basis of the variation in susceptibility to the obesogenic environment is important because it will provide insights into inter-individual susceptibility to weight gain and will help focus support on children with the greatest chance to benefit.

Figure 1.1 Change in the distribution of BMI between 1976–1980 and 1999–2004 for children and adolescents aged six to 19 years in the United States (Wardle & Boniface, 2008)



1.2 Appetite and childhood weight

The Behavioural Susceptibility Model of obesity **(Figure 1.2)** proposes that the basis for a gene-environment interaction is that 'obesity genes' are influencing weight, at least partly through an appetitive pathway. In particular, individuals that inherit a set of genes that confer greater responsiveness to external food cues (wanting to eat when you see, smell or taste palatable food), and lower sensitivity to satiety ('fullness') are more likely to overeat in response to the current obesogenic environment, and to become obese (Carnell & Wardle 2008). The model takes into account the role of social factors such as food availability, and metabolic factors such as satiety hormones, and proposes that these factors not only have a bi-directional relationship with appetite, but also have a direct relationship with energy intake. For example, under conditions of famine, no-one would become obese, regardless of genetic susceptibility and appetitive characteristics.

For many years it has been acknowledged that the eating behaviours of overweight individuals differ from those of healthy weight individuals. The 'externality theory' of obesity was put forward by Stanley Schachter in 1968 when, during a variety of experimental studies, he observed that obese individuals responded more strongly to external cues of food (sight, smell and taste) but less strongly to internal sensations related to hunger and satiety (feelings of fullness) than healthy weight individuals (Schachter 1968). A number of experiments in the 1990s also demonstrated that overweight children were more likely to eat beyond fullness in response to the presence of palatable foods than healthy weight children (Fisher & Birch 2002; Hill et al. 2008; Lansigan et al. 2015; Johnson & Birch 1994).

In support of the Behavioural Susceptibility Model, food responsiveness and satiety responsiveness have been shown to have a strong genetic basis in both infancy (Llewellyn et al. 2010) and childhood (Llewellyn et al. 2008; Carnell et al. 2008). Heritability estimates have been found to be as high as 75%; supporting an appetitive pathway for 'obesity genes'. There is now considerable evidence that food responsiveness and satiety responsiveness play an important role in weight gain during childhood. This is summarised in the section below, along with a critique of the measurement methods.

1.2.1 Measuring appetite in children

Existing research into the relationship between appetite and weight in childhood has utilised a variety of different methodologies including behavioural methods (usually in the form of laboratory-based measures of eating behaviour) and psychometric methods (standardised questionnaires).

1.2.1.1 Behavioural methods

Predominantly three behavioural paradigms have been used in research to assess satiety responsiveness and food responsiveness; food cue reactivity tasks, the energy compensation paradigm and the eating in the absence of hunger paradigm.

Research into food cue reactivity is based on conditioning theory; after repeated associations between sensory cues and food intake, the cues alone begin to signal food. Once the cues become good predictors of intake, they elicit physiological responses useful for digestion, for example salivation, and this is termed ‘cue reactivity’. Tasks assessing food cue reactivity assess the extent to which a child will increase food intake in response to seeing, smelling or tasting highly palatable foods. Children are exposed to sensory food cues in the experimental condition, or no food cues in the control condition. Food consumption is then assessed in both groups following exposure. If children are highly responsive to the food cues, it is expected that those in the experimental condition will consume more of the palatable foods than those in the control condition (Jansen et al. 2003).

Eating in the absence of hunger (EAH) is a term first coined in the late 1990s to refer to eating beyond fullness in response to the presence of palatable foods (Fisher & Birch 1999). EAH paradigms involve measuring children’s intake of palatable snack foods when they are made freely available, following a meal during which they have eaten to satiety. This paradigm is thought to tap food responsiveness only, because the children are instructed to eat the prior meal until they feel full. Nevertheless, it is possible that subsequent intake of palatable foods may also partly reflect lower sensitivity to satiety for some children.

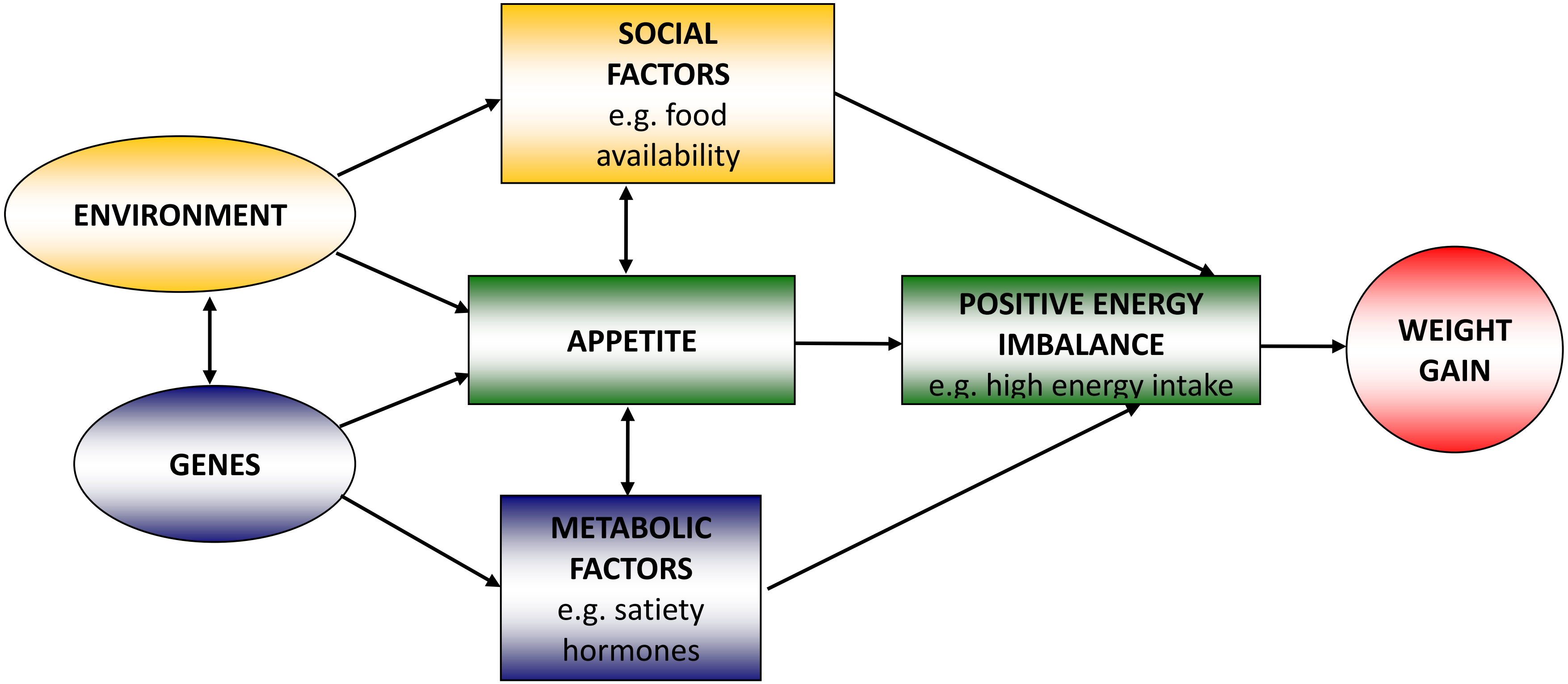


Figure 1.2 The Behavioural Susceptibility Model of obesity (Carnell & Wardle 2008)

The energy compensation paradigm tests whether children decrease their ad libitum food intake in response to increasing energy density or a ‘preload’ (in the form of food or a drink given prior to a meal). Each child's intake of palatable food is measures with no preload, as well as after a preload, and energy intake is compared across the two conditions. The method assumes that if an individual consumes a preload and is then given a meal to consume, those with good internal sensitivity to satiety will regulate their intake at the meal by consuming less in proportion to the amount of energy consumed in the preload. This adjustment in energy intake is termed energy compensation and a compensation score (COMPX) can be calculated which indicates how much they compensated for the preload during the meal. The COMPX formula is: ((Ad-libitum intake $KJ_{low\ energy\ preload}$ – Ad-libitum intake $KJ_{high\ energy\ preload)}$ / (Preload KJ_{high} – Preload KJ_{low})) x 100% (Johnson & Birch 1994). Perfect energy compensation would be shown if a child has a COMPX score of 100%.

1.2.1.1.1 Limitations of behavioural studies in children

Behavioural methods have the advantage of providing an objective means of assessing appetite in children. However, they can be expensive to set up and run and are often carried out on a relatively small scale. There is also the possibility that children may respond differently in an experimental setting than they would in an everyday context as a result of being observed, usually in a laboratory (Wardle et al. 2001). Behavioural experiments also simply provide a snapshot of behaviour (a single eating episode), and it is therefore difficult to make assumptions about the underlying behavioural traits that may influence eating behaviour and dietary intake within an everyday context (Epstein 1983).

1.2.1.2 Psychometric methods

Psychometric measures (standardised questionnaires) lose the objectivity offered by behavioural assessments, but have the advantage of providing more than just a snapshot of behaviour at one moment in time. Individuals provide responses that describe their ‘usual’ behaviours or more general traits, rather than being influenced by individual situations that may not reflect the ‘norm’ or may not generalise from that instance of the behaviour (Wardle et al. 2001). For example, a person’s eating behaviour in an experimental setting when presented with a plate of palatable snacks following a meal may not necessarily reflect how they eat more generally in everyday life across eating occasions. Questionnaires are easy to administer and psychometric studies can be conducted on a large-scale at a relatively low cost.

Self-report questionnaires are, however, open to subjectivity, and are limited in their use with young children because an understanding of the questions being asked and self-awareness of the behaviours at hand are required. Parents however observe their children within their natural environment and are able to respond to questionnaires on their child's behalf. The downside, of course, is the possibility of socially desirable responses, and particularly for eating behaviours, parents can only report on those that they have observed (Carnell & Wardle 2007). Nevertheless, standardised parent-report questionnaires provide a convenient means of establishing children's habitual appetitive characteristics. They are inexpensive and easily distributed, so can be administered on a large scale, maximising statistical power.

1.2.1.2.1 Dutch Eating Behaviour Questionnaire (DEBQ)

The Dutch Eating Behaviour Questionnaire [DEBQ] (Van Strien et al. 1986) (**Appendix 1.1**) is a 33-item questionnaire developed to assess restrained eating (intentional restriction of energy intake), emotional eating (over-eating in response to emotions such as anxiety, anger, upset) and external eating (eating in response to external food stimuli such as the sight or smell of food, regardless of feelings of hunger). There is a parent-report version for nine to 12 year olds (DEBQ-P) (Caccialanza et al. 2004) as well as a child-report version for seven to 12 year olds (DEBQ-C) (Van Strien & Oosterveld 2008). The DEBQ-P and DEBQ-C have both been shown to have good internal consistency (Cronbach's alphas ranging from 0.77 to 0.86, and 0.73 to 0.82 respectively) (Halvarsson & Sjoden 1998; Van Strien & Oosterveld 2008). The DEBQ has limitations in that it has not been consistently validated using laboratory or naturalistic studies (Domoff et al. 2014), it assesses just three aspects of eating style and does not include a measure of satiety sensitivity.

1.2.1.2.2 Child Eating Behaviour Questionnaire (CEBQ)

The most frequently used measure to assess appetite in children today is the Child Eating Behaviour Questionnaire (CEBQ) **(Appendix 1.2)** (Wardle et al. 2001). This measure, developed in 2001, assesses eight aspects of eating behaviour that are hypothesised to relate to weight in children. In particular, two 'food approach' behaviours indicate higher appetitive responses: 'Food Responsiveness' (FR), 'Enjoyment of Food' (EF), and three 'food avoidance' behaviours which indicate lower appetitive responses: 'Satiety Responsiveness' (SR), 'Slowness in Eating' (SE) and 'Food Fussiness' (FF). Two scales measure eating in response emotions;

assessing the tendency to over-eat in response to negative emotional states ('emotional overeating'), and under-eat in response to negative emotions ('emotional under-eating'). 'Desire to drink' assesses a child's approach behaviours towards drinks. The CEBQ has been validated with behavioural studies (Carnell & Wardle 2007). A modified version of this measure, adapted for use with toddlers (CEBQ-T) **(Appendix 1.3)** is used throughout thesis and is described in more detail in **Chapter 3.** The majority of the items in the CEBQ and the CEBQ-T are identical. However, the Emotional Undereating and Desire to Drink scale from the original CEBQ have been removed, and some items within the CEBQ were re-worded to be age-appropriate for toddlers. There is also a baby version of the CEBQ; the Baby Eating Behaviour Questionnaire (BEBQ) (Llewellyn et al. 2011) which was developed using scales from the CEBQ deemed appropriate for infants who are still exclusively milk-fed. The measure contains 17 items that assess 'food responsiveness', 'enjoyment of food', 'satiety responsiveness' and 'slowness in eating'.

1.2.2 Current evidence for associations between appetite and weight in children

1.2.2.1 Behavioural evidence

There is a wealth of behavioural research to suggest that overweight children exhibit different eating behaviours to healthy weight children, and a number of behavioural paradigms have been used to explore this. The evidence is reviewed below.

1.2.2.1.1 Food cue reactivity and weight

Compared with healthy weight children, overweight children respond more strongly to food cues, shown by a greater energy intake following food cues such as the sight or smell of palatable foods (Jansen et al. 2003; Cutting et al. 1999; Halford et al. 2004; Halford et al. 2007). In a study by Jansen et al (2003) the intake of highly palatable snack foods following food cues was explored in obese and healthy weight children (*n*=31) aged eight to 12 years. Children were exposed to an intense smell of tasty snack foods for 10 minutes and then presented with seven large dishes of sweet and salty snacks: M&M's, sugar peanuts, small pieces of cake, pieces of Milky Way, crisps, and savoury nuts. The child was invited to taste the foods and consume as much as they wanted. The remaining food was weighed. Overweight children consumed more food than healthy weight children following the exposure to food cues (Jansen et al. 2003).

Another study explored the effect of television food adverts on food intake in 59 (32 male, 27 female) children aged nine to 11 years of age. The children were tested on two occasions separated by two weeks. In one condition children viewed 10 minutes of food adverts followed by a cartoon, in the other condition the children viewed 10 minutes of non-food adverts followed by the same cartoon. After this, children were presented with an assortment of foods; Snack-a-Jacks; Haribo sweets; Cadbury's chocolate buttons; potato crisps; and grapes. Food intake and choice was assessed. Significant increases in energy intake were observed following exposure to food adverts; all children, regardless of weight status (healthy weight versus overweight) consumed more following exposure to the food adverts. However, the largest increase in food intake was observed among overweight children (Halford et al. 2008). The study was repeated in a younger sample of five to seven year olds and no effect of weight group was found (Halford et al. 2007). This suggests that food cue reactivity might be a trait that is expressed as children get older.

1.2.2.1.2 Eating in the absence of hunger and weight

Studies involving the EAH paradigm suggest that overweight children are more susceptible to continued eating when satiated, in response to the presence of palatable food, than healthy weight children. A study by Fisher & Birch (2002) assessed whether young girls' EAH at five and seven years of age was associated with an increased risk of overweight. The participants (*n*= 192, non-Hispanic, white) were given a standard ad-libitum lunch (bread, sandwich meat, carrots, applesauce, cheese, cookies and milk), and then given free access to 10 sweet and savoury snack foods (popcorn, potato chips, pretzels, nuts, fig bars, chocolate chip cookies, fruit-chew candy, chocolate bars, ice cream, and frozen yogurt). Energy intake from snack foods was assessed and it was found that girls who consumed more energy in the absence of hunger at age five and seven years were significantly more likely to be overweight at both time points (Fisher & Birch 2002).

Another study by Hill et al. (2008) explored cross-sectional associations between adiposity and eating in the absence of hunger in two samples of children. The first sample included 348 children aged seven to nine years and their intake of highly palatable sweet snacks was assessed 20 minutes after a mixed meal at school. The other included 316 children aged nine to 12 years and their intake of palatable sweet snacks was assessed at home. In both studies, BMI predicted EAH in boys, but there was no association among girls. Weight groups (underweight, lower healthy weight, higher healthy weight, overweight, obese) were also compared using linear trend analyses. In the first study, EAH increased progressively with adiposity in boys, but among girls EAH increased from underweight, through lower and higher healthy weight, but decreased slightly for overweight and obese girls. The gender difference may, however, be due to social desirability pressures that constrained food intake in overweight girls, especially since the children were tested and weighed in school. In addition there was an under-representation of overweight (11%) and obese (5%) children in the study. In the second sample, a significant linear trend was observed across the weight groups, but again just in boys and not girls, and interestingly in this study social desirability may have played less of a role as children were tested in their home. The authors concluded that in boys at least, EAH appears to be a behaviour that is not specific to overweight children but in fact shows a graded association with adiposity across the weight continuum. They noted, however, the importance of exploring eating behaviours free of the influence of social desirability (Hill et al. 2008). Research that does not involve direct observation of children by researchers would be one way to potentially overcome this limitation.

Shunk & Birch (2004) investigated associations between EAH and weight status longitudinally in a sample of 153 girls aged five to nine years. Girls at risk of overweight at aged five consumed more food in the absence of hunger at age seven and age nine than children not at risk of overweight. Whilst this study suggests that weight status influences later eating behaviours, the causal direction of the relationship is unclear as adjustment was not made for earlier eating behaviour or weight status. Nevertheless, the evidence from behavioural studies suggests that heavier children exhibit different eating behaviours than lighter children, but as described earlier, behavioural methods are limited. They only offer insight into behaviour at any one time and in order to characterise more habitual eating behaviours, psychometric measures are required. Also, the foods used across studies varies, as do other aspects of the design such as the time between the preload and subsequent meal. This means that the way in which eating behaviour is measured is not standardised across studies.

A recent systematic review was conducted of 12 cross-sectional, six prospective, and one intervention study that have explored EAH and weight in children (<12 years of age). It concluded that evidence consistently supports higher levels of EAH among overweight and obese children than healthy weight children (Lansigan et al.

2015). This was the case both cross-sectionally and prospectively, and suggests that overweight children respond more strongly to food, and will consume more food even when they are not hungry.

1.2.2.1.3 Energy compensation and weight

Studies that have used the energy compensation paradigm to explore associations between adiposity and energy compensation have proved inconsistent. Some studies show that increased adiposity is associated with poorer compensation in response to preloads (Johnson 2000; Johnson & Birch 1994). An early study by Johnson & Birch (1994) of 77 three to five year olds explored children's ability to regulate their energy intake in response to changes in energy density. Children were given one of two food preloads, varying in energy density (628 kJ/g versus 13 kJ/g) and then given an ad libitum lunch. They found a relationship between adiposity and energy regulation; children with greater fat stores (assessed by weight (kg), and triceps and subscapula skinfold thicknesses) were less able to regulate their intake of the lunch meal following the high energy dense preload than those with lesser fat stores (Johnson & Birch 1994). Jansen et al. (2003) assessed snack intake following a preload (in addition to food cue reactivity) in a sample of 31 children aged eight to 12 years. Children were given a preload (611 kJ) of the snack foods (M&M's, sugar peanuts, cake, MilkyWay, crisps and savoury nuts) to consume over 10 minutes. All participants ate the entire preload. Snack food intake was then assessed in the free access condition and overweight children consumed more food than healthy weight children following the preload (Jansen et al. 2003). A study by Kral et al. (2012) utilised both a preload and an EAH design to assess energy compensation and EAH across 47 same-sex sibling pairs (53% female) aged five to 12 years who were discordant for weight. The siblings were served the same dinner (pasta with tomato sauce, broccoli, applesauce, and milk) once a week for three weeks (three visits). On visit one no preload was consumed but on visits two and three, twenty-five minutes before dinner, children consumed one of two preloads (vanilla or chocolate puddings). The preloads varied in energy density (ED) (2.38 and 4.06 kJ/g). The energy (kJ) consumed from snacks (potato chips, baked snack crackers, wafer biscuits, sponge cake with cream filling, chocolate chip cookies, and milk chocolate) was assessed after dinner. Overweight/obese siblings showed a lack of compensation insofar as they consumed more after the high ED preload, whereas healthy weight siblings showed accurate compensation. Overweight/obese siblings consumed a third more energy in the absence of hunger than did healthy weight siblings, however overweight children also had higher energy requirements so energy intake per se may not have truly reflected 'over-eating'. Assessment of energy intake as a percentage of energy requirements would be necessary to determine this (Kral et al. 2012).

These studies suggest that overweight children have lower internal responsiveness to satiety than healthy weight children. However, other studies have demonstrated null associations between weight status and energy compensation. Faith et al (2004) assessed food intake following a preload in a sample of three to seven year olds (*n*= 32) and all children demonstrated reasonable compensation accuracy, regardless of weight status (Faith et al. 2004). However, the sample was small making it unlikely that a significant association would be detected. Another study conducted by Cecil et al (2005) explored energy compensation in six to nine year olds (*n*= 74). They had three preload conditions; a no-energy condition (250 ml water), low energy condition (782 kJ) and high-energy condition (1628 kJ). The latter conditions both used a 250 ml orange drink and a muffin weighing 56 grams so that the conditions were matched for taste and volume but differed in energy content. Ninety minutes after the preload, the children were given a test meal. No association was observed between energy intake at the test meal and weight; with all children adjusting their intake according to the energy content of the preload. Johnson and Taylor-Holloway (2006) measured food intake on two occasions following juice preload drinks of different energy contents (628 kJ versus 13 kJ) in five to 11 year old children (*n*= 262). No association was observed between intake and weight, and almost all children adjusted their intake. Younger children showed better compensation than older children (Johnson & Taylor-Holloway 2006).

1.2.2.2. Psychometric evidence

The Food Responsiveness (FR) subscale of the CEBQ assesses the extent to which a child responds to external food cues such as the smell or sight of food. Parents rate descriptions of eating behaviours that characterise food responsiveness on a scale of one (never) to five (always). Items include: “even if my child is full up s/he finds room to eat his/her favourite food”; and “if allowed to, my child would eat too much”. The continuum of scores (from one to five) reflects the least food responsive (score of one) to the most food responsive (score of five) children. The CEBQ Satiety Responsiveness (SR) scale indicates the extent to which a child responds to internal feelings of satiety. Questions such as "my child cannot eat a meal if s/he has had a snack just before" and “my child gets full before his/her meal is finished” assess this trait and scores range from one (least satiety responsive) to five (most satiety responsive).

There has been a wealth of research into cross-sectional associations between both FR and SR and weight status in children using the CEBQ. Studies tend to demonstrate that overweight children score higher on the FR subscale, and lower on the SR than healthy weight children (Eloranta et al. 2012; Jansen et al. 2012; Santos et al. 2011; Spence et al. 2011; Webber et al. 2009; Lumeng et al. 2014; Carnell & Wardle 2008). Data from a population-based cohort in the Netherlands, involving 4987 children aged four years demonstrated that children scoring higher on the FR subscale and lower on the SR subscale were at greater risk of overweight than those scoring lower and higher respectively (Jansen et al. 2012). Another study of Chilean children (*n*= 294) aged six to 12 years demonstrated similar associations; SR was inversely associated with weight status (healthy weight, overweight and obese), whilst FR was positively associated with weight status (Santos et al. 2011). A UK study of 406 children aged between seven and 12 years of age also demonstrated significant linear trends by weight category (underweight, lower healthy weight, higher healthy weight, overweight, obese). A positive linear trend was shown for FR and a negative linear trend for SR (Webber et al. 2009). Another study in 2011 explored relationships between appetitive traits and weight (underweight, healthy weight, at risk of overweight, overweight) in four and five year old Canadian children (*n*= 1730). Graded positive linear patterns by weight were found for food responsiveness and graded negative linear patterns by weight were found for satiety responsiveness (Spence et al. 2011). This study had the advantage of researcher measured heights and weights, and used the validated CEBQ to measure appetite.

In addition to distinguishing the clinically overweight/obese from the non-clinical, both high food responsiveness and low satiety responsiveness have also shown cross-sectional associations with higher adiposity in a linear fashion across the spectrum of weight (Wardle et al. 2008; Cross et al. 2014; Domoff et al. 2015; Frankel et al. 2014; Fuemmeler et al. 2012; Sleddens et al. 2008; Mackenbach et al. 2012; Hathcock et al. 2014; Haycraft et al. 2011; Llewellyn et al. 2014; Svensson et al. 2011; Vollmer et al. 2015; Spence et al. 2011; Carnell & Wardle 2008). One of the first studies to assess associations between adiposity and the two appetitive traits of FR and SR was conducted in 2008 and included two samples of children in the UK. The first sample was 10,364 children aged eight to 11 years, drawn from a population-based twin cohort; the Twins Early Development Study (TEDS). The second sample included three to five year olds (*n*= 572) from a community sample, recruited through preschool classes in 16 primary schools in London, England. Parents completed the CEBQ and adiposity was indexed with BMI (kg/m2), adjusted for the age and sex of the child. Waist circumference was also used as an adiposity measure. In both samples, higher BMI was associated with lower satiety responsiveness and higher food responsiveness. Data were also analysed by weight categories (lower healthy weight, upper healthy weight, overweight, obese). In both samples, children in higher weight categories had lower satiety responsiveness and higher food responsiveness. This study suggests that FR and SR both show a graded relationship with adiposity, such that lower satiety responsiveness and higher food responsiveness are associated with increasingly higher adiposity (Carnell & Wardle 2007).

There is consistent evidence relating lower satiety responsiveness to greater adiposity, however some null associations have been reported between food responsiveness and adiposity in children. A study by Sleddens et al (2008) involved 135 parents of primary school children (six and seven years old) in the Netherlands completing the CEBQ. Children's BMI was converted into standardised z-scores and the association between mean FR and SR scores and child weight status were examined. Linear regression analyses demonstrated a significant increase in BMI with FR, and a linear decrease with SR. However, whilst there were significant differences in mean SR score between weight categories (underweight, healthy weight, overweight), with overweight children scoring lower, there were no differences in mean FR score between weight categories (Sleddens et al. 2008). Another small-scale cross-sectional study involved 296 low-income African-American mothers of pre-school children (two to five years old) completing the FR subscale of the CEBQ. No associations were found between FR scores and BMI SDS or BMI centile category (<5, 5–14.9, 15–84.9, 85–94.9, >95) (Powers et al. 2006). However, in both of the studies showing null findings, the samples were small (<300 children) and there may have been insufficient power to detect significant associations.

All of the studies described above were cross-sectional in nature, so it is not possible to make inferences about causal relationships between FR and SR and weight. Prospective studies help to establish the most likely direction of the relationship between appetite and weight, and there have now been a number of these studies using the CEBQ. FR and SR have both been shown to predict weight gain prospectively in children (van Jaarsveld et al. 2011; Parkinson et al. 2010; Deutekom et al. 2016; Disantis et al. 2011; Gregory et al. 2010a; Mallan et al. 2014; Steinsbekk & Wichstrøm 2015; Steinsbekk et al. 2016). Prospective associations between appetitive traits and weight have been found in the Gemini twin cohort; FR, SR and weight were measured at three months using the infant version of the CEBQ (BEBQ), and at 15 months of age using the CEBQ-T. The pathways between both FR and SR at three months of age and weight at 15 months of age were significantly stronger than those between weight at three months and FR and SR at 15 months; suggesting that differences in FR and SR influence weight gain more powerfully than weight influences appetite in early life (van Jaarsveld et al. 2011).

Another study involving the Gemini twin cohort explored whether sibling differences in appetite (assessed using the BEBQ) predicted differential weight gain during childhood. 172 appetite-discordant (defined as a within-pair difference of at least one standard deviation for FR or SR) pairs of non-identical twins were included in the study. Growth trajectories for the higher-appetite vs lower-appetite twins from birth to 15 months of age were assessed. The appetite-discordant twins grew at different rates from birth to 15 months, with the more food responsive and less satiety sensitive twin growing faster than his or her co-twin. Twins with the higher FR and lower SR were on average one kg heavier than their co-twin at 15 months. The study concluded that a more avid appetite (indexed with higher FR or lower SR) in early infancy is prospectively associated with more rapid growth up to age 15 months (van Jaarsveld et al. 2014). This lends support to a causal role for appetite in childhood weight gain, however the study was conducted in twins and therefore gives no indication of the generalizability of the findings to the wider population. However, analyses of a UK longitudinal birth cohort, the Gateshead Millennium Study, of both singletons and twins has demonstrated similar prospective associations. Parents of 419 children completed the CEBQ when they were five to six years old. Relationships between the child's appetite and later BMI at six to eight years of age were explored. SR but not FR at five to six years of age was a significant predictor of BMI at seven to eight years (Parkinson et al. 2010). However, while adjustment was made for age, sex and birth weight, baseline BMI was not adjusted for. It could well be that BMI at five to six years was driving later weight at seven to eight years, rather than appetite.

A more recent study that addressed this limitation was recently conducted in 995 Norwegian children. Data on appetite were collected using the CEBQ, and used to predict change in BMI SDS from age six to eight years. In addition, the effect of BMI SDS from age four on later appetite was also explored. High FR aged six years predicted a steeper increase in BMI SDS from age six to eight years. There was no association for SR. A reversed effect was also observed in that higher BMI SDS at four years of age predicted increased FR and decreased SR between age six to eight (Steinsbekk & Wichstrøm 2015). This study supports previous research in that it suggests that food responsive children show increased weight gain, but in contrast to the other prospective studies mentioned above, satiety responsiveness did not predict weight gain. This was a large, representative sample but it was limited by the infrequent assessment of BMI every two years. Studies with frequent assessments of child height and weight would help to overcome this limitation.

In summary, a large research base supports the hypothesis that two aspects of appetite - food responsiveness and satiety responsiveness - are consistently associated with weight, and appear to drive weight gain during early childhood. Children who are more food responsive and/or less satiety responsive tend to be heavier and gain weight at a faster rate than less food responsive and/or more satiety responsive children.

1.3 Appetite and eating behaviour

The relationships between both food responsiveness and satiety responsiveness and weight are well established in children, through both laboratory-based experimental measures and psychometric measures. Children tend to be heavier, and gain more weight if they are more food responsive and/or have lower satiety responsiveness. Food responsiveness and satiety responsiveness therefore appear to be part of the complex model that determines variation in weight but *how* children exhibiting these traits might consume excess energy in daily life is worthy of exploration. The 'everyday' eating behaviours and dietary mechanisms through which these appetitive traits predispose to weight gain are unknown. There has been considerable research into the relationship between *what* children eat (e.g. the quality of their diet) and weight/weight gain, but less attention has been focused on *how* they eat – consumptions patterns, such as how much and how often they eat. In addition, during early life milk is a primary source of energy, but the transition from milk feeding to solid food has never been explored in relation to appetite. *How* children eat and drink may be just as important for weight gain as *what* children eat and drink, and the role of appetite in this needs to be explored.

1.3.1 Measuring dietary intake in children

Accurate assessment of children's dietary intake is essential in order to determine the role of diet in obesity. Collecting reliable dietary data in children, however, can present a number of practical and methodological challenges. Until approximately eight years of age, children's ability to report their dietary intake is limited because the cognitive abilities required to self-report food intake are not well enough developed. Individuals require a good concept of time, a good memory and attention span, and a knowledge of the names of foods (Livingstone & Robson 2000). This means that parents are often used as proxy reporters of children's dietary intake in early to mid-childhood. There are a number of possible methods in which diet can be assessed in children, each with advantages and disadvantages. These are critiqued below.

1.3.1.1 Food Frequency Questionnaires

Food frequency questionnaires (FFQs) are commonly used to measure dietary intake in children because they are inexpensive and easy to administer. They tend to involve parents reporting their child's usual frequency of consumption of various foods from a given list for a specific period of time. While this gives an idea of frequency of consumption, very little other information is collected, such as the amount (grams or energy intake) of food and drinks consumed. Therefore, it provides a very broad overview of an individual's diet that relies on the listed items and assumed portion sizes. This greatly limits the ability to estimate individual energy intake. Semi-quantitative FFQs collect more information about portion size and these can then be used to calculate nutrient intakes, but nevertheless an individual's diet cannot be captured with any precision. FFQs also require individuals to remember the items consumed, usually over the past week, and this lends itself to error (Kristal et al. 2005). A study by Burrows et al. (2013) assessed the validity of energy intake reports using a child-specific FFQ compared to the Doubly Labelled Water (DLW) method. The latter is considered the gold standard method for estimating total energy expenditure (TEE) and is described in more detail below. DLW was assessed over a ten day period and the Australian Child and Adolescent Eating Survey (ACAES) was used to compare the accuracy of total energy intake reporting across the two methods. The sample included nine children aged eight to 11 years. Mothers, fathers and children were each asked to independently complete the FFQ which recorded the frequency of 120 food items consumed over the previous six months; and the accuracy of the reported energy intakes from all three reporters was assessed. This was done by calculating the absolute difference (energy intake minus energy expenditure) between the energy intakes reported in the FFQ and those from the DLW method. The mean difference in energy intake between the two measures were found to be 544 kJ for child reports (473 ± 35% of TEE), 1665 kJ for father reports (506 ± 13% TEE), and 3376 kJ for mother reports (602 ± 26% TEE). Child FFQ reports were the closest to those observed using DLW, indicating that children were the most accurate reporters (Burrows et al. 2013). It also suggests that parental reports of dietary assessment using FFQs may not be particularly reliable. The study is limited by the small sample size, and the two methods (FFQ and DLW) assessed diet over different time periods; the DLW method assessed energy expenditure over ten days which is unlikely to reflect the six month period assessed with the FFQ.

1.3.1.2 24 hour dietary recall

24-hour recall of dietary intake involves parents reporting all food and drinks consumed by their child in the previous 24 hours. This method can be self-administered, computer-assisted or conducted via an interview that reduces the time taken to complete it. The main disadvantages are the over-reliance on memory which can mean recall is inaccurate; many parents are not with their child over an entire 24 hour period (Fries et al. 1995), and it only provides one day's intake which may not be representative of a child's average intake (Johnson, Driscoll, & Goran, 1996).

1.3.1.3 Doubly Labelled Water (DLW)

The DLW method estimates TEE from which energy intake (EI) can then be inferred. It is based on the premise that metabolism can be calculated from oxygen-in/CO_2-out. When an individual consumes doubly labelled water, ($^2H_2{}^{18}O$), deuterium (^2H) leaves the body as water, while ^{18}O leaves as water (H_2O) and carbon dioxide (CO_2). Therefore, CO_2 production can be calculated by subtracting ^2H elimination from ^{18}O elimination. The CO_2 loss gives an indication of the energy produced (TEE). This is typically measured over a period of seven to 14 days, incorporating short-term day-to-day variation in physical activity. It still does not, however, account for seasonal variation in physical activity levels or other situations that affect energy expenditure with time. A review that included individuals aged six to 74 years demonstrated the coefficient of variation for repeated measurements of energy expenditure by DLW was 8-10% (Black & Cole 2000). Nevertheless, in free-living, weight-stable populations energy expenditure as measured by DLW is reflective of actual energy intake (Roberts et al. 1995). DLW can be used to provide an independent and objective means of validating dietary intake data, but it is seldom used as it is very expensive and requires high technical skills and facilities. In addition, it only assesses total energy intake and no other nutrients, and it cannot be used to explore *how* energy is consumed over a number of days, for example the size and frequency of eating occasions.

1.3.1.4 Diet diaries

Assessing diet in children using diet diaries usually involves parents or a carer recording the food and drinks consumed by their child, either over three, five or seven days, in real-time. Non-consecutive days of intake are often preferred because food and drinks consumed on consecutive days may be associated, for example eating leftovers from a meal the previous day. By collecting dietary information over a number of days, averages can be computed to give a more accurate picture of an individual's usual intake. Diet diaries completed in real-time also reduce error due to memory loss as foods and drinks are recorded as they are consumed. The amount consumed can be measured (weighed diet diaries) or estimated using images (unweighed diet diaries). Unweighed diet diaries have been used in two large-scale UK population surveys; the National Diet and Nutrition Survey (NDNS) (Whitton et al. 2011) and the National Diet and Nutrition Survey of Infants and Young Children (DNSIYC) (Stephen et al. 2013a), and have been validated against data collected using weighed dietary records (Lanigan et al. 2001; Crawford et al. 1994; Bingham et al. 1994). Diet diaries are able to provide an indication of daily energy and nutrient intake and patterns of eating behaviours.

1.3.1.5 Evaluation of dietary assessment methods

A number of studies have been conducted to compare dietary assessment methods. One such study compared dietary data collected via direct observation, a FFQ and a 24 hour recall, with that collected using diet diaries in 58 girls, aged nine to 10 years. All methods introduced some error, but the diet diaries showed the best agreement with direct observation (Crawford et al. 1994). In another study seven different methods of dietary data collection, including a diet diary, FFQ and 24 hr recall, were compared to a 16 day weighed diet record in 160 women aged 50-65 years. Individual estimates of nutrients from the unweighed diet diary were most closely associated with intakes from the weighed diary (Bingham et al. 1994). Unweighed diet diaries are considered a rigorous and reliable method for dietary assessment, but they can be time consuming to complete and also require the respondent to be highly literate. This can result in selection bias and an over-representation of motivated and educated individuals who may not be representative of the population from which the sample was drawn. Nonetheless, a recent systematic review of dietary assessment methods concluded that diet diaries conducted over at least a three day period, including weekdays and weekends, using parents as proxy reporters is the most accurate method to estimate total energy intake in children, compared with total energy expenditure measured by DLW (Burrows et al. 2010).

1.3.2 Defining eating patterns

Childhood obesity is a complex issue and there are likely to be multiple contributory factors but inevitably if an individual consumes more energy than they expend, they will gain weight. *What* individuals eat is therefore important; for example, if an individual consumes a lot of energy dense foods they will have a higher daily energy intake than someone who consumes a lot of low energy dense foods. However, daily energy intake can be conceptualised as the number of times an individual consumes food and drink per day (termed 'meal frequency' throughout this thesis), multiplied by the amount of energy consumed each time (termed 'meal size' throughout this thesis). Therefore, not only *what* but also *how* individuals eat might be important; the patterning of energy intake (meal size and frequency) may play a role in weight gain. However, defining and assessing eating patterns is difficult as there is currently no consensus in the literature as to what constitutes a meal, snack or eating occasion (Oltersdorf et al. 1999; Chamontin et al. 2003).

Some studies have used self-reported classifications of meals and snacks (Francis et al. 2003; Huang et al. 2004; Keast et al. 2010; Lioret et al. 2008; Preston & Rodriguez-Quintana 2015) but these are subjective classifications and open to individual bias. Other studies have used more objective criteria such as the timing of eating occasions (Jennings et al. 2012), the energy content of the foods consumed (Eloranta et al. 2012) or simply classified any occasion in which food or drink is consumed as an eating occasion (Kontogianni et al. 2010; Murakami & Livingstone 2014; Ritchie 2012). To add to the heterogeneity, studies have used different methods of assessment, for example FFQs versus diet diaries, making comparisons between studies difficult. Given the numerous ways in which eating patterns have been defined and assessed in the literature it is difficult to draw conclusions from research exploring *how* children eat. This highlights the need for standard definitions of eating patterns. Nevertheless, the evidence for the relationship between appetitive traits and eating patterns is reviewed below.

1.3.3 Current evidence for associations between appetite and eating patterns

Food responsiveness and satiety responsiveness could conceivably be characterised by distinct patterns of eating that predispose to overconsumption, and overweight. Food responsiveness (the tendency to want to eat in response to food cues) might predict the initiation of eating, while satiety responsiveness (one's fullness threshold) might predict eating offset. In the modern food environment food is abundant, cheap, easily accessible and widely advertised, so children who are highly responsive to food have many opportunities to act on their urge to eat. At the same time, if a child takes longer to feel full, or has less sensitive fullness signals, they may eat more on each occasion in order to feel satisfied. However, until now the relationships between these eating patterns and appetitive traits have never been explored within an 'everyday' context. In addition, there are few laboratory-based studies. As far as I can determine there are only four existing studies, all of which were laboratory-based. One has explored the effect of experimentally-manipulated meal frequency and size on satiety, another three have explored how natural variation in satiety sensitivity predicts intake patterns in the laboratory.

A relatively recent review of eating behaviours and their associations with energy intake (French et al. 2012) highlighted just one cross-sectional study by Carnell & Wardle (2007) that had explored associations between FR, SR, as measured with the CEBQ, and energy intake. Behavioural measures of energy intake (energy intake at a meal, EAH and energy compensation) were used to validate the CEBQ in a sample of 111 four to five year old British children. SR was associated with lower energy intake during the lunch meal, in the EAH task, and following a preload. Higher scores on FR were associated with greater energy intake at the lunch meal, but were not associated with EAH or energy compensation. The authors suggest that potentially the behavioural measures used in the study reflected SR more than FR. They proposed that FR might be more strongly related to eating behaviour in other circumstances, such as when children are presented with a self-serve buffet, or when they are able to 'graze' over a longer time period (Carnell & Wardle 2007). It is possible that food responsiveness might express itself more fully in eating behaviours in the real-world context, for example in response to the frequency with which individuals come into contact with food. This highlights the importance of exploring appetite and food intake within an everyday context. Currently no studies have explored the relationship between FR and SR and children's energy intake by characterising ecologically valid behaviours derived from sources such as daily food diaries.

A more recent study assessed variation in SR and FR, measured using the CEBQ, and meal energy consumed in 100 non-Hispanic black children five to six years of age. The children were presented with a meal on four different occasions over weekly visits, differing in portion size. The energy consumed during each meal was explored in relation to SR and FR. A main effect was found for SR and meal size such that children with lower SR consumed more energy during each meal; on the other hand, there was no main effect for FR and meal size (Mooreville et al. 2015). This is in line with that found by Carnell & Wardle (2007). However, there was an interaction effect for both SR and FR; as portion sizes increased more energy was consumed by children with higher FR and lower SR scores. This suggests that not only do children with lower SR consume larger meals, but high food responsiveness and low satiety responsiveness appear to increase children's susceptibility to consuming more in response to larger portions. This has implications for preventing excess weight gain among children susceptible to overconsumption; for example, individuals showing higher FR and lower SR could be offered smaller portions. However, it is unclear whether these findings would translate into eating behaviour outside the laboratory setting. The portions consumed by children in everyday life are likely to be influenced by how often they are eating; young children who eat frequently have been shown to consume smaller portions, and those who eat larger portions have been found to eat less often (Fox, Devaney, et al. 2006). Again, this highlights the need to explore how meal size might be associated with appetite in the real-world, when other aspects of eating patterns, such as meal frequency, are considered.

One other experimental study by Mehra et al (2011) explored the relationship between eating patterns and satiety sensitivity using a visual analogue scale or "Freddy" scale. 35 children aged six to ten years of age were given either three or five meals on their first of two visits to the lab, and the alternate meal pattern on visit two the next day. Both meal patterns were equal in energy content and children were asked to rate how full they felt using the visual analogue scale. After each meal pattern (i.e. after three or five meals) children were offered four pre-measured bowls containing one, two, three, or four scoops of chocolate or vanilla ice-cream depending on their flavour preference. They were asked if they would like some ice-cream and instructed to select the bowl they wanted. They were instructed to inform the investigator when they had finished eating and asked to rate their level of fullness. This ice-cream scenario was then repeated. Fullness ratings did not differ by meal pattern either after the meals or after the ice-creams, indicating that consuming a greater number of smaller meals or consuming fewer larger meals did not affect how full children felt in an experimental context. An interesting observation however, was that pre-ice-cream fullness ratings were associated with subsequent intake of ice-cream in both the three and five meal conditions, with those who rated themselves as less full consuming more ice-cream (higher energy intake), independent of meal frequency (Mehra et al. 2011). This might suggest that individual differences in satiety sensitivity within the sample of participants determined the amount of food consumed, rather than the frequency of eating. However, this was an experimental study that studied the effects of meal pattern manipulation on satiety, not the other way around. It therefore did not shed light on how variation in satiety sensitivity or food responsiveness translates into the patterning of eating behaviour in an everyday context.

Mallan et al (2014) conducted a study involving 37 children and measured SR at two years of age using the CEBQ, and energy intake at four years of age using the EAH paradigm. Mothers were asked to select a lunch meal for their child from a list of items, and then 15 minutes after consuming this the children were given free access to snacks (bite-sized savoury biscuits, sweet biscuits, fruit ‘leathers’ (flat, pectin-based fruit-flavoured snack), crisps, and a cereal bar). The snacks provided a total of 2070 kJ. Children scoring lower on SR at two years of age consumed more energy during the lunch meal at four years of age than those scoring higher on SR, suggesting they were less responsive to feelings of satiety and as a result consumed larger amounts (Mallan et al. 2014). SR was not associated with intake of snacks post-meal. FR was not associated with energy intake during the lunch meal, or from snacks post-meal, and this concurs with both of the cross-sectional studies that have explored FR and energy intake (Carnell & Wardle 2007; Mooreville et al. 2015). However, this study was not truly prospective as baseline intake of energy intake was not adjusted for. Also, as alluded to earlier, it is possible that FR does not express itself in experimental settings as these may not reflect habitual behaviours. However it may be expressed in response to everyday situations such as seeing sweets at the till in the supermarket, smelling fresh cakes walking past a bakery, or being offered cake at a birthday party. In addition, this study contained just two overweight children which means there was less variation in the sample. This may explain the null findings with food responsiveness given that overweight children tend to be more food responsive than healthy weight children.

All the studies mentioned above had small sample sizes (*n*= 111, 100, 35 and 37 respectively). Research using dietary data from large samples of children, and collected as and when the child eats and drinks is needed to understand how the eating behaviours of children with these appetitive traits translate into an everyday context. Characterising the specific aspects of eating behaviour that lead to overconsumption in these children would provide useful targets for behavioural interventions for the prevention of excessive weight gain.

Further research is needed to characterise the eating patterns - specifically the size and frequency of eating occasions - that are associated with naturally occurring variation in appetitive traits in the 'real world'. Exploration of these subtle eating patterns is required because if children's appetites play a role in specific patterns of eating, this has practical implications for the development of interventions to prevent excess weight gain in early life.

The literature reviewed above has been summarised in tables presented in **Appendix 1.4**.

1.4 The role of eating patterns in childhood weight

In addition to exploring whether children's appetites play a role in specific patterns of eating, it is important to establish whether specific patterns of eating are associated with childhood weight.

Population trends indicate an increase in the number *and* size of eating occasions consumed among US children between 1977 and 2010; a period during which children's weights increased substantially at the population level (Duffey & Popkin 2011; Popkin & Duffey 2010). A study by Nielsen & Popkin (2003) explored dietary data from 63380 individuals aged two years and older. Data came from the Nationwide Food Consumption Survey (1977-1978) (Rizek 1978) and the Continuing Survey of Food Intake by Individuals (1989-1991, 1994-1996, and 1998) (Tippett 2000; Tippett & Cypel 1998). The authors were interested in whether there had been changes in the portion sizes consumed for a number of foods (salty snacks, desserts, soft drinks, fruit drinks, french fries, hamburgers, cheeseburgers, pizza, and Mexican food). They found that between 1977 and 1996 portion sizes increased both inside and outside the home for all foods except pizza. The energy intake and portion size of salty snacks increased by 389 kJ, soft drinks by 205 kJ, hamburgers by 406 kJ, french fries by 285 kJ, and Mexican food by 556 kJ. The largest increases were observed for foods consumed within the home and fast food outlets, as opposed to within restaurants (Nielsen & Popkin 2003).

Other studies have demonstrated increases in portion sizes for some foods in some settings (Young & Nestle 2002; Moreno et al. 2010; Matthiessen et al. 2003). A US study conducted in 2002 measured the current portions (weights) of food within the most popular take-out and fast food outlets and family-type restaurants, and foods such as white bread, cakes, alcohol and sodas. They then compared them to US dietary guidelines and to food portions offered since the 1970s. They found that with the exception of white bread, all commonly available food portions exceeded dietary guidelines and had increased in size since the 1970s. In the 1950s the fast-food chain McDonalds only offered one size for fries but that is now the 'small' size (Young & Nestle 2002). Studies such as this often result in messages being delivered on 'appropriate' portion sizes, but this concerns the broader population exposures rather than addressing differences in eating behaviour that could lie behind differential risk of obesity. The trends reported here may help to explain *population changes* in weight, but they do not necessarily explain *individual differences* in weight. There is weight variation among the population suggesting there might be individual differences in eating patterns. Over recent years there has been increasing research interest in eating patterns and adiposity; more specifically whether eating larger meals (meal size) or eating more frequent meals (meal frequency) is associated with weight in children. To explore this, requires an exploration of associations between adiposity and the size and frequency of meals *consumed*.

1.4.1 Current evidence for associations between meal frequency and childhood weight

Meal frequency is often targeted in public health campaigns, with advice to limit between-meal snacks a common feature. However, the evidence surrounding the relationship between eating frequency and weight, especially in young children, is mixed. The majority of research in this area has been conducted cross-sectionally, limiting the conclusions that can be drawn with regards to causation. Only two cross-sectional studies to date have reported a positive association between eating frequency and weight in infants and very young children. Zhang et al. (2009) showed higher meal frequency to be associated with higher adiposity; indexed using a variety of anthropometric measures (weight-for-age Z score [WAZ] and weight-for-length Z score [WLZ]) in 501 infants aged six to 11 months (Zhang et al. 2009). However, meal frequency was defined by assigning points to each infant based on them meeting age-specific recommendations for meal frequency. For example, two points were given if the recommended meal frequency was reached, and one point given if the meal frequency was less than the recommendation but not zero. As the actual number of meals consumed was not used in the analyses this may have impacted findings. A larger, more recent study also showed a positive association between eating frequency; reported using a FFQ, and weight status, in 4552 children aged 10-12 years. Overweight children had more frequent eating occasions (meals and snacks) (Farajian et al. 2014), but FFQs are unlikely to accurately reflect habitual intake.

Aside from these two studies, the majority of cross-sectional research into eating frequency and weight in children suggests there is an inverse association between eating frequency and adiposity; usually indexed with BMI (Barba et al. 2006; Beyerlein et al. 2008; Fábry et al. 1966; Keast et al. 2010; Murakami & Livingstone 2014; Würbach et al. 2009) and also with weight status. Overweight children tend to consume fewer meals than healthy weight children (Bo et al. 2014; Cassimos et al. 2011; Eloranta et al. 2014; Jääskeläinen et al. 2013; Lagiou & Parava 2008; Mota et al. 2008; Neutzling et al. 2003; Preston & Rodriguez-Quintana 2015; Toschke et al. 2005; Vik et al. 2010). A recent meta-analysis by Kaisari, Yannakoulia, & Panagiotakos (2013) analysed findings from ten cross-sectional studies and one case-control study (21 sub-studies in total) exploring eating frequency and weight associations in children and adolescents. The study, comprising 18,849 participants aged two to 19 years, concluded that higher eating frequency was associated with lower weight in children and adolescents. However, just one study in the meta-analysis involved a sample of children younger than three years of age (McConahy et al. 2002), and it is possible that older children's reports of eating frequency are influenced by their current weight status, for example skipping meals in an attempt to lose weight. In addition, under-reporting food intake is common in overweight and older children (Huang et al. 2004).

There is a dearth of research exploring meal frequency and weight in preschool children. As far I can determine, only two studies have explored meal frequency and weight associations in children younger than three years of age. One, described above, found a positive association between meal frequency and adiposity (Zhang et al. 2009). The other found no difference in the number of eating occasions consumed per day between overweight and healthy weight infants aged one year (McConahy et al. 2002). One potential reason for these discrepancies across the two studies may be because Zhang et al. (2009) used a composite measure of eating frequency in which children were given an eating frequency score based on how well they met age-specific recommendations for meal frequency. McConahy et al. (2002) however utilised two day diet diaries as the method of assessment, with meal frequency as the actual number of reported eating occasions per day consumed rather than a composite measure.

A number of other studies with older children have also reported null findings for the association between meal frequency and BMI (Coppinger et al. 2012; Murakami & Livingstone 2015) or weight status (Antonogeorgos et al. 2012; Ferreira & Marques-Vidal 2008; Jennings et al. 2012; Kontogianni et al. 2010; Maffeis et al. 2008; Nicklas et al. 2003). However, results from these studies should be interpreted with caution as there are a number of methodological limitations; for example, the majority of studies have used non-validated, self-report questionnaires to assess eating frequency (Antonogeorgos et al. 2012; Barba et al. 2006; Beyerlein et al. 2008; Cassimos et al. 2011; Farajian et al. 2014; Ferreira & Marques-Vidal 2008; Jääskeläinen et al. 2013; Kosti et al. 2007; Lagiou & Parava 2008; Maffeis et al. 2008; Mota et al. 2008; Neutzling et al. 2003; Toschke et al. 2005; Toschke et al. 2009; Turkkahraman et al. 2006; Vik et al. 2013; Würbach et al. 2009), and few studies have assessed actual eating frequency with the use of dietary recall or diet diaries (Coppinger et al. 2012; Eloranta et al. 2014; Francis et al. 2003; Franko et al. 2008; Huang et al. 2004; Jennings et al. 2012; Lioret et al. 2008; McConahy et al. 2002; Murakami & Livingstone 2014; Ritchie 2012; Zerva et al. 2007). In addition, the majority of studies have all been cross-sectional which makes it impossible to determine the likely direction of causation. An inverse association between eating frequency and BMI might reflect overweight children actively limiting the number of snacks they eat in an attempt to control their weight, or it could suggest that eating less frequently does actually lead to higher weight. In order to try and establish the direction of the association between meal frequency and weight gain, longitudinal research is needed; and preferably in younger samples before they have gained excessive weight.

To date just three longitudinal studies have explored the role of meal frequency in weight gain during childhood (Francis et al. 2003; Franko et al. 2008; Ritchie 2012). Francis et al (2003) assessed snacking frequency in five-year-old girls using parent-reported three day food diaries and its association with change in BMI up to age nine years. No association was found between snacking frequency and weight gain (Francis et al. 2003).

In 2008 a study was conducted by Franko and colleagues to explore associations between meal frequency at nine years of age and BMI-for-age z-scores at 19 years of age. Participants were 2375 girls (49% white, 51% black ethnicity) enrolled in the National Heart, Lung and Blood Institute Growth and Health Study (NGHS) (Morrison et al. 1992). Meal frequency was determined using self-reported three day food diaries, with dietician-coded meals and snacks. Children eating more than three meals per day had lower BMI-for-age z-scores at nine years of age and lower increases in BMI up to age 19 years. However, there was no association between meal frequency and weight status (overweight versus healthy weight) up to 19 years of age. Interestingly there was an interaction by race such that black girls who ate three or more meals on more days were less likely to be overweight (Franko et al. 2008). This study suggests that consuming at least three meals per day may be helpful in preventing overweight. However, there may be inaccuracies in self-report diet diaries during adolescence as a result of under-reporting (Livingstone et al. 2004).

A more recent longitudinal study by Ritchie (2012) used a large sample of 2372 girls nine to ten years old to assess eating frequency and weight gain over a 10-year period. Three day food diaries (self-report) were used to calculate the total number of eating occasions per day which were then categorised as 1-3, 3-4, 4-6, >6 per day. Lower eating frequency was associated with greater 10-year increases in BMI and waist circumference (Ritchie 2012).

The latter two studies suggest that less frequent eating predicts higher BMI. However, the samples involved girls only and it is unknown whether the findings would also generalise to boys as well. In addition, the two samples involved children over the age of five. It is possible that under-reporting was an issue, and eating behaviours may have already been influenced by current weight status, for example skipping meals in an attempt to lose weight. Both methodological issues are seen more commonly in older children (Woodruff et al. 2008; Boutelle et al. 2009; Weden et al. 2013). Different definitions of eating occasions were also used within these studies so it is difficult to make comparisons. A recent study by Murakami & Livingstone (2015) used different definitions of meals and snacks to explore the relationship between eating frequency and adiposity in British children aged four to 10 years (*n*= 818) and adolescents aged 11–18 years (*n*= 818). They used two definitions of meals: i) any eating episode equal or greater than 15% of total energy intake (other occasions were defined as snacks), and ii) eating episodes occurring at the following times of day; 06.00–10.00, 12.00–15.00 and 18.00–21.00 hours (all other occasions were defined as snacks). They found that regardless of the definition used for classifying meals or snacks, there was no association between meal or snack frequency and adiposity (Murakami & Livingstone 2015).

In summary, there are inconsistent associations between meal frequency and weight in children and many studies have not included both boys and girls in the same sample. There are few prospective studies so more research exploring the relationship between meal frequency and weight gain in young children is needed. Younger age groups are ideal for exploring this because parents tend not to perceive young children as overweight (Syrad et al. 2014; Falconer et al. 2014) and therefore parental under-reporting may be less likely (Macdiarmid & Blundell 1998).

The literature reviewed above has been summarised in tables presented in **Appendix 1.5.**

1.4.2 Current evidence for associations between meal size and childhood weight

Current early years feeding advice is often underpinned by the adage ‘mother provides, baby decides’; based on the assumption that so long as the food quality is good, the child’s appetite can be relied upon to regulate an appropriate energy intake (Fox, Devaney, et al. 2006). However, if some children, do not have satiety mechanisms that are sensitive enough to match their intake to their energy needs, meal size may be an important element of obesity risk; especially in an environment where much of the food they are offered is highly palatable.

Few studies have explored the relationship between meal size and weight in children in an experimental setting. There are even fewer studies that have explored this within the normal home environment, in young children. Experimental studies tend to serve children foods varying in portion size and assess energy intake by weight status, as well as portion size condition. Four experimental studies have been carried out (Kral et al. 2014; Mooreville et al. 2015; Savage, Fisher, et al. 2012; Savage, Haisfield, et al. 2012) and three of these demonstrated that not only did overweight children consume larger amounts during meals than healthy weight children, they also consumed more in the larger portion conditions than healthy weight children did (Kral et al. 2014; Savage, Haisfield, et al. 2012; Savage, Fisher, et al. 2012). The other study found that the effect of portion size condition on energy intake did not vary by weight status (Mooreville et al. 2015).

The first study presented meals in six different portion sizes (100g, 160g, 220g, 280g, 340g and 400g) to healthy weight (*n*= 11) and overweight (*n*= 6) children aged three to six years old. As portion sizes increased, overweight children consumed significantly more energy than healthy weight children (Savage et al. 2012). In another, more recent study, 50 children aged eight to 10 years were presented with three meals on three separate occasions, each time varying the portion size (100%, 150%, 200%). Overweight children (≥85th percentile for their age- and sex-adjusted BMI) consumed significantly more energy during each meal than healthy weight children. In addition, they showed significantly greater increases in energy intake as portion sizes increased (Kral et al. 2014). This suggests overweight children may be more susceptible to overconsuming in response to larger portions than healthy weight children, potentially because they have lower sensitivity to satiety or greater responsiveness to food cues. However, the third, more recent experimental study demonstrated no association between weight status and energy consumed during test meals, regardless of portion size condition. 100 children aged five to six years were presented with four meals at different time points, each varying in portion size (energy content) (2832, 4247, 5661 and 7075 kJ). There was no main effect of weight status (healthy weight versus overweight) and no interaction between weight status and portion size, on energy consumed (Mooreville et al. 2015).

As discussed earlier, however, experimental research does not give an indication of eating behaviours within a naturalistic setting. Studies that assess children's more habitual dietary intake are needed. A small handful of researchers have attempted this, using an array of methods to assess dietary intake. One such study, conducted by Bau et al (2011) used a FFQ to compute daily portion size scores of 15 food groups for 1519 children aged 11-14 years. Children were asked to report the portions they would usually consume for each food (one handful= one portion; two times one handful= two portions; three to four times one handful= three to four portions; and >four times one handful= more than four portions). Using this, a portion size score was computed which characterised portions as 'optimal', 'normal' or 'unfavourable'. Weight status, categorised using WHO classifications (underweight<18kg/m², healthy weight=18-24.9kg/m², overweight >24.9kg/m) was not associated with portion size scores (Bau et al. 2011).

In a somewhat similar study by Colapinto et al (2007) children aged 10 to 11 years (*n*= 4966) were asked to indicate the portion size they usually consumed of four food items (French fries, meats, cooked vegetables and potato chips) using 3D food models. Food containers were used to indicate the portions of French fries, modelling clay was used for meats, bean bags for vegetables, and different sized potato chip bags for the potato chips. These portions were then referenced against appropriate portion size guidelines and deemed to be less than or equal to the reference portion size. There was no association between the probability of overweight and portion sizes of any of the four food items (Colapinto et al. 2007). Conversely, an observational study by Lin et al (2013) found a positive association between meal size and weight status in children aged three to seven years. Teachers estimated age-appropriate portion sizes of rice and cooked dishes according to children's age and then used this as a basis to compare and report on the portions consumed by 1138 children. The energy intake of each child's lunch was then computed by measuring the weight of the reference portion size of rice and cooked dishes. Children consuming larger meals during their school lunch were significantly more likely to be overweight than those consuming smaller meals.

As discussed earlier, diet diaries are considered the most reliable and rigorous method to assess eating patterns. However, just four studies to date have used diet diaries as a measure of habitual intake to explore meal size and weight associations in children, all of which have been cross-sectional (Albar et al. 2014; Huang et al. 2004; Lioret et al. 2009; McConahy et al. 2002). Lioret et al (2009) used data from seven day food and drink diaries to explore the portion sizes (grams and energy density) of a number of food groups (sweet or savoury snacks, breakfast cereals, cheese, meats) and their associations with weight status (overweight versus healthy weight). They found that among three to six year olds (*n*= 340), the portion sizes of sweetened pastries was associated with overweight, and among seven to 11 year olds (*n*= 408) the portion size of liquid dairy products (milk, milkshakes and yoghurt drinks) was associated with overweight. No other associations with weight status were found for other food groups (Lioret et al. 2009).

In a similar study exploring the portion sizes of food groups and weight, Albar et al (2014) found that among 636 children aged 11-18 years, there was a positive association between BMI and the portion sizes of energy dense foods such as nuts, chocolate, and pizza (Albar et al. 2014). Identifying relationships between the portion sizes of specific foods and adiposity is important, especially in an environment in which highly palatable foods are widely available and relatively cheap. However, it is important to also explore portion sizes of eating occasions over the course of a day as this will provide a clearer indication of more habitual eating behaviours and how the size of portions consumed might relate to adiposity.

Two day food diary data from the Continuing Surveys of Food Intakes by Individuals (1994-1998) explored daily eating occasions (number of meals and snacks) and found a significant positive association between the meal size (energy content) of eating occasions and weight status (healthy weight versus overweight) in six to 11 and 12 to 19 year olds, but not in three to five year olds. However, there was no formal test of the interaction with age (Huang et al. 2004). The only study involving children under three years of age found that portion size (grams) consumed per eating occasion was positively associated with body weight. Parents of 899 one year old children completed two day food diaries and associations were explored between portion size and weight status (under-weight<15th percentile, healthy weight= 15th to 85th percentile, and overweight ≥85th percentile) (McConahy et al. 2002). The study suggested that heavier children consumed larger amounts of food, however portion size was assessed only in grams, and this gives no indication of the types of foods or the energy content of foods consumed, which is likely to play a significant role in weight (Bell & Rolls, 2001; Levine, 2001).

In summary, cross-sectional research is yet to determine how meal size is associated with weight in young children. There is a need to focus not only on the quantity (grams) but also the amount of energy (kJ) and composition (energy density, energy from macronutrients) of eating occasions. There are currently no prospective studies so the role of meal size in weight gain is unknown.

The literature reviewed above has been summarised in tables presented in **Appendix 1.6**.

1.4.3 The interplay between meal size and meal frequency and effects on energy intake

There is some evidence that young children seem able to regulate their energy intake by reducing or increasing their energy intake per meal based on the number of meals per day (Lipps & Deysher 1986; Fomon et al. 1975). In other words, if a young child eats frequently, they tend to eat smaller amounts each time to compensate. In a study of 3,022 children aged four to 24 months, those who ate less often during the day consumed larger portion sizes; and children who ate more often during the day consumed smaller portions (Fox, Devaney, et al. 2006).

However, other studies have shown that from as early as six weeks old, children's energy intake is influenced by serving size (Dewey & Lonnerdal 1986; Looney & Raynor 2011; Birch et al. 2003; Fisher 2007). In a study by Dewey & Lonnerdal (1986) mothers of 18 breastfed infants aged six to 21 weeks were instructed to express extra breast milk as a means of increasing milk production. In response to increased maternal milk supply infants had a greater energy intake and there was a positive association between increased milk intake and infant weight-for-length (Dewey & Lonnerdal 1986). Birch et al (2003) served 35 children aged three to five years old one of two entrees differing in portion size and measured energy intake of the entrée and a subsequent lunch. Regardless of age, the children served larger entrees consumed more energy both from the entrée and the lunch meal (Birch et al. 2003).

As described above, McConahy et al (2002) used two-day diet diaries to explore associations between both meal size (grams per eating occasion) and meal frequency, and weight in 899 one-year old children. They found that meal size but not meal frequency predicted weight status, but also that meal size but not frequency predicted daily energy intake (McConahy et al. 2002). This suggests that meal size may be a bigger contributor towards energy intake than meal frequency, at least in very young children. Confirmed in a later study, McConahy et al. (2004) showed that while daily energy intake (also assessed using two day food diaries) in two to five year old children was positively related to both the frequency and size (grams consumed) of eating occasions, size was the biggest contributor (McConahy et al. 2004).

To summarise, it appears that although children appear to regulate energy intake to some extent, there are factors that may interrupt this. Previous literature has demonstrated that children consume more when served larger portions (Fisher et al. 2003; Rolls et al. 2000; Small et al. 2013), and it is therefore possible to see how the proposed compensatory mechanism of energy regulation may be inadequate for some children to maintain energy balance and prevent weight gain.

1.4.4. The relative role of meal size and meal frequency in weight gain

To date, associations between meal size and meal frequency in childhood weight gain have not been established. Just three studies have explored both meal parameters within the same sample (Huang et al. 2004; Lioret et al. 2008; McConahy et al. 2002), and all have been cross-sectional in nature. Lioret et al (2008), described above, found an inverse association between meal frequency and overweight in three to 11 year olds, and found overweight was positively associated with the portion size (grams and energy density) of sweetened pastries in three to six year olds, and with liquid dairy products in children seven to 11 years. However, exploring food groups does not give a clear indication of habitual eating patterns in the same way as daily eating occasions would.

The study by McConahy et al (2002) looked at eating occasions rather than food groups, and showed that meal size (grams per eating occasion) but not meal frequency was associated with higher weight (McConahy et al. 2002). The difficulty, however, with using the weight of eating occasions to index portion size, is that some foods can be very heavy but contain low amounts of energy, for example soups which contain large amounts of water but have a low energy content so they have a low energy density (kJ/g). Similarly, energy dense foods such as chocolate can be low in weight (g) but high in energy (kJ). Using energy content rather than weight to index portion size is therefore important. Huang et al. (2004) explored associations between meal size, meal frequency and weight in three age groups: three to five, six to 11 and 12 to 19 year olds. They defined meal size by the energy consumed per eating occasion (kJ) rather than the weight (g), assessed using two day food diaries. Meal size but not meal frequency was positively associated with BMI in six to 11 and 12 to 19 year olds, but there were no associations between either meal size or meal frequency and weight in three to five year olds (Huang et al. 2004).

In the two latter studies both the size and frequency of eating occasions were explored, and heavier children consumed more energy than lighter children, by consuming larger meals. The number of meals was not, however, associated with weight status. The cross-sectional nature of the studies means that the results might simply reflect the fact that heavier children have greater energy requirements and therefore consume larger portions. They do not indicate whether the heavier children were over-consuming by eating larger meals, thereby exceeding their energy requirements and subsequently gaining weight.

In summary, there are currently inconsistent associations between the relative role of meal size, meal frequency and weight in children. No prospective studies have been conducted into these associations so it is unclear how each of these meal parameters might be associated with weight gain during early childhood. This is an area worthy of exploration, and it is key that the size of eating occasions in terms of both their energy content (kJ) and weight (grams) should be considered.

1.5 Current evidence for the continuity and stability of weight, appetite and eating patterns in children

Weight during childhood is known to track over time, with overweight children more likely to become overweight adolescents and adults (Mo-suwan et al. 2000; Johannsson et al. 2006; Nicklas et al. 2006; Singh et al. 2008; Wang et al. 2000; Serdula et al. 1993). A review of the literature in 1993 suggested that the risk of an obese child becoming an obese adult was between two and seven times more likely than for non-obese children (Serdula et al. 1993). A more recent study of 841 young adults explored the tracking of overweight from age nine to eleven, up to age 19-35 in Euro-Americans (68%) and African-Americans (32%). A correlation of 0.66 was found between baseline and later BMI (Nicklas et al. 2006). Studies involving infants have demonstrated that those at the highest end of the distribution for weight or those who grow rapidly during infancy are at increased risk of subsequent obesity (Baird et al. 2005; Druet et al. 2012). This highlights the need to identify factors such as appetitive traits and eating behaviours that may be influencing weight gain from early on in life.

Appetitive traits have been shown to be relatively stable during childhood. Ashcroft et al (2008) examined continuity in CEBQ scores from age four to 11 years and showed that children who scored relatively highly on both food responsiveness and satiety responsiveness at age four also scored relatively highly on those traits at 11 years of age, with correlations of 0.44 and 0.46 respectively (Ashcroft et al. 2008). However, they also noted that children became more ‘appetitive’ as they got older. Satiety responsiveness reduced, and food responsiveness increased significantly over time, suggesting an increased likelihood of children overeating as they get older. The stability of FR and SR from early life to mid-childhood has not previously been explored. It might be the case that early appetite might not track as strongly from toddlerhood as eating behaviours are only just developing as children are weaned onto solid food.

Food and taste preferences have also been shown to track from early childhood to later childhood (Lioret et al. 2013; Skinner et al. 2012; Madruga et al. 2012; Nicklaus et al. 2004), and dietary exposure during the early years may influence longer-term food choices (Northstone & Emmett 2008; Nicklas et al. 1991; Nicklaus & Remy 2013). One study by Nicklaus et al (2004) explored the relationship between food choices at two to three years of age on food preferences later in life. The food choices of 342 children in a nursery canteen between 1982 and 1999 were assessed and then in 2001-2002, when the children were aged between four and 22 years of age, their present preference for foods was assessed again. Categories included vegetables, animal products, cheeses, starchy foods and combined foods. For most categories, current preference was associated with earlier preference at two to three years old; suggesting that preferences were stable from two to three years until young adulthood (Nicklaus & Remy 2013). With this in mind, it is possible that eating patterns – meal size and frequency – during early life may also track into later childhood. This has never been explored but is an important area of research. If young children consuming large meals and/or eating frequently continue to do so, this has implications for potential overconsumption and weight gain. In addition, if eating patterns show stability from early to late childhood, it might be possible for healthy eating patterns to be established during early life and maintained throughout adulthood.

In summary, weight, appetitive traits and food preferences have been shown to track during childhood, but the stability of eating patterns (the size and frequency of eating occasions) has never been explored. In order to identify pathways between appetitive traits, eating patterns and weight from early to middle childhood it is necessary to explore whether these meal parameters track over time in the same sample of children. To date no research has explored stability and change of appetite and eating patterns in a sample of very young children from early to mid-childhood.

1.6. Conclusions and future research

Previous research consistently demonstrates that children who are more food responsive and less satiety responsive gain weight at a faster rate. It has not been demonstrated just h*ow* children's eating behaviours and dietary intake might influence weight gain, and how appetitive traits might play a role.

Few studies have explored the relative roles of both meal size and meal frequency in weight, as information on both parameters has not typically been collected in the same study. There are no longitudinal studies that have concurrently explored these meal parameters as predictors of weight gain during early childhood.

It is possible that eating patterns (meal size and meal frequency) may mediate the associations between appetite and weight in children but to date no research has explored this or the relative importance of each and their inter-relationships. The dietary mechanisms that may increase the susceptibility of individual children to weight gain is an important area for further research.

CHAPTER 2. RESEARCH AIMS OF THE CURRENT THESIS

2.1 Aims and outline of the research in the current thesis

Overall the aim of this thesis was to identify behavioural pathways through which individual differences in appetite may result in weight gain. I have used data from the Gemini twin birth cohort to explore interrelationships between appetite, eating patterns, diet and weight, during early childhood. Specifically it aims to: (i) describe the dietary intake of young children; (ii) explore associations between appetite, eating patterns, and dietary intake; (iii) identify associations between eating patterns and weight gain; (iv) examine the mediation of the appetite-weight relationship by eating patterns; and (v) assess the continuity and stability of appetite and eating patterns from early to middle childhood. **Figure 2.1** shows the chronological order of the studies contained within this thesis and describes how the ideas emerged.

The first chapter of this thesis summarised consistent evidence for associations between appetitive traits and weight during childhood; children who show greater food responsiveness and lower satiety responsiveness gain weight at a faster rate and are at greater risk of overweight. It also showed there is a lack of research into the ‘everyday’ eating behaviours through which these appetitive traits might translate into weight gain. *How* children eat may be just as important for weight gain as *wha*t children eat, but the inter-relationships between appetite, eating patterns (size and frequency of eating occasions) and weight gain remain largely unexplored. A greater responsiveness to food cues might be expected to increase the frequency of eating given the high cue exposure in modern environments. Lower responsiveness to internal satiety cues might be expected to increase the size of an eating occasion as individuals might continue to eat if they take longer to feel satiated or do not recognise feelings of satiety. However, there have been no detailed studies of the patterning of young children’s daily energy intake (how much and how often children eat) in an everyday context, in relation either to appetite or weight. The overall aim of the current thesis is to explore the possibility that the size and/or frequency of eating occasions is associated with weight gain in children, and that these eating patterns help to explain why children with specific appetitive traits gain excess weight. In order to explore this, I will conduct a number of studies, outlined below.

Study 1: Dietary intakes of young children in the UK

Current intakes of toddlers beyond 18 months in the UK have not been explored. The Gemini twin study is a large population based cohort and provides an opportunity to examine *what* (food and drink intake, and energy, macronutrient and micronutrient intake) and *how* (how often and how much) young children are eating and drinking in relation to UK dietary guidelines. That was the primary aim of this study. Due to the twin nature of the sample, comparison with dietary data from a sample of young singletons in the UK provides the opportunity to demonstrate whether dietary data from the Gemini sample is a valuable resource for further research into diet and health outcomes in young children.

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Study 2: The role of appetite in formula milk and food intake during early life

Study 1 highlighted that at 21 months of age, children in the Gemini cohort consumed almost 25% of their energy intake in milks. In addition, 13% still consumed formula milk, despite recommendations that the transition from a primarily milk-based diet to a modified version of the family diet should occur by this age. This study sought to use quantitative (a validated measure of appetite) and qualitative (telephone interviews with mothers) methods to better understand the reasons for some children continuing on formula into later toddlerhood.

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Study 3: Appetitive traits and consumption patterns in early life

Study 2 demonstrated that children with less avid appetites were more likely to still consume formula milk at 21 months, and that maternal decisions appeared to be driven by their child's relative lack of interest in, and low intake of, solid food. This suggested that appetite might not only play a role in *what* children consume during early life, but might also play a role in *how* they consume it (how often and how much). Study 3 therefore explored the role of appetitive traits (Food Responsiveness and Satiety Responsiveness) in everyday patterns of intake (meal frequency and meal size). The aim was to determine the behavioural aspects of eating that are associated with traits that have been linked to weight gain in early life.

Study 4: Consumption patterns in early life and adiposity

Study 3 demonstrated that children with higher food responsiveness eat more often and children with lower satiety responsiveness eat more each time they eat. It is possible that by eating too often and/or eating too much, a child will gain excessive weight but this has been largely unexplored in the literature. The primary aim of this study was to identify relationships between the patterning of energy intake (meal size and frequency) in early life and weight gain.

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Study 5: Meal size as a mediator of the association between satiety responsiveness and adiposity

Study 3 had demonstrated that children with lower satiety responsiveness consumed larger meals, and study 4 demonstrated that larger meals, but not more frequent meals drove weight gain in early childhood. This suggested that meal size might mediate the association between satiety responsiveness and weight in children; children with lower Satiety Responsiveness (SR) potentially gain weight as a result of their susceptibility to consuming larger meals. Study 5 therefore examined the behavioural pathway through which children with lower satiety sensitivity might gain weight.

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Study 6: Stability and change of dietary intake and appetite from early to mid-childhood

Given the inter-relationships observed in early life between appetite, dietary intake and weight gain, this final study sought to explore the stability and change in these factors from 21 months to seven years of age in a sub-sample of 200 children. Children consuming higher intakes of energy and nutrients, those eating larger amounts and those eating more frequently tend to continue to do so as they get older. Appetitive traits show continuity over time, suggesting children will not ‘grow out of’ their eating habits. This, in combination with the previous five studies, highlights the importance of establishing a healthy diet and eating habits in early life which will continue into later childhood, potentially shaping weight trajectories.

Figure 2.1. Flowchart of studies within this thesis

2.1.1 Dietary intakes of young children in the UK

If an individual has a higher energy intake than energy expenditure they will gain weight. Therefore, it is important to understand *what* children are eating, as well as *how* they are eating, and the potential impact of this on daily energy intake. In addition to the influence of diet on weight gain, there may also be long-term consequences of a poor diet on health so it is important to establish healthy eating habits early in life. Good quality data on young children's diets is essential in order to identify dietary factors or eating behaviours that might contribute to weight gain and/or poor health.

There have only been a few detailed large-scale national studies of dietary intake in young children in the UK, and a gap in the literature exists in relation to current intakes of toddlers beyond 18 months. **Chapter 4** aims to use comprehensive dietary data from 2336 children aged 21 months, collected in 2008/09 using three day unweighed diet diaries to describe young children's dietary intakes. The daily energy and nutrient intakes from food and drinks, and the average size and frequency of eating and drinking occasions will be described. Comparisons will be made with data from 386 children aged 18-36 months from the National Diet and Nutrition Survey (NDNS) rolling programme (2008-2012). In addition, comparisons will be made with UK public health nutrition recommendations to assess whether children are meeting dietary guidelines.

2.1.2 The role of appetite in formula milk and food intake in early life

The transition from a primarily milk-based diet to a modified version of the family diet should have occurred by 12 months of age, yet previous studies have demonstrated that many children in the UK are consuming formula milks beyond this age (Fox et al. 2004; Lennox et al. 2013). Extended formula feeding (beyond 12 months) has been deemed unnecessary by a number of governing bodies (UNICEF UK Baby Friendly Initiative 2010; Department of Health 2012; Department of Health 2008; European Food Safety Authority 2013; World Health Organisation 2005), and it is possible that if given in addition to food, formula milk may provide excess energy and contribute to obesity risk. **Chapter 5** seeks to identify if formula milk consumption at 21 months of age is associated with increased energy intake and higher weight gain during early childhood. It also aims to explore *why* children continue to consume formula milk beyond the recommended age. Previous research has suggested that parents adapt their feeding behaviours based on aspects of their child's appetite, and this chapter therefore aims to explore the role of appetite in parental feeding decisions during the complementary feeding period.

2.1.3 Appetitive traits and eating patterns in early life

A large body of research shows that children who are more responsive to external food cues (higher food responsiveness) and/or less responsive to internal cues for satiety (lower satiety responsiveness) are at increased risk of obesity. However, the underlying behavioural mechanisms through which these appetitive traits predispose to overweight are unclear. When presented with food in experimental tasks, children with lower satiety responsiveness or higher food responsiveness will eat more than children who are more satiety responsive or less food responsive; but it is not known how children with these traits might eat outside of an experimental setting, within an ‘everyday’ context. It is possible that children with lower satiety responsiveness consume more food each time they eat (larger meal sizes). Children with higher responsiveness to food cues might also consume larger meals if palatable food continues to be available; but food responsiveness could also be an eating onset trait as food cues might elicit an urge to eat. **Chapter 6** aims to gain a better understanding of the everyday eating patterns that characterise higher food responsiveness and lower satiety responsiveness, in young children.

2.1.4 Eating patterns in early life and adiposity

The importance of *what* children eat for health has long been established; if a child consumes more energy per day than they require and expend, they will gain weight over time. However, *how* individuals eat, not just *what* they eat, may also play an important role in weight trajectories. Eating too often (a high ‘meal frequency’) and eating too much energy each time (a large ‘meal size’) could lead to overconsumption. However, children are thought to regulate their energy intake so as not to overeat. In particular, it is widely believed that young children will compensate for a large meal by eating less frequently, and will compensate for frequent eating by eating less each time (Fox, Devaney, et al. 2006). But what if some children are less able to regulate their intake in an environment in which food is palatable, easily available and served in large portions? There are no existing studies that have prospectively explored the relative contribution of meal size and meal frequency to excess weight gain or obesity risk in early childhood using the same sample over the same recording period. **Chapter 7** aims to do just that and explore i) longitudinal associations between the size and frequency of both eating and drinking occasions at 21 months and weight gain up to age five; ii) characterise the relationships between the size and frequency of eating and drinking occasions; (iii) examine associations between the size and frequency of eating and drinking occasions at 21 months and weight status at two and five years of age; (iv) examine the composition of eating occasions (energy density and macronutrient composition) by weight status at two and five years of age, and v) establish the generalizability of the Gemini findings to the general population, by replicating the cross-sectional findings in a nationally representative sample of UK singletons aged four to 18 months.

2.1.5 Appetite, eating patterns and adiposity

Children with lower responsiveness to satiety and higher responsiveness to food cues are more susceptible to weight gain, but the behavioural pathway through which this might occur is unknown. Experimental literature suggests that children exhibiting these traits consume more food when given free access to palatable snacks. Therefore it could be hypothesized that children with these appetitive traits gain weight because they consume more energy each time they eat. No research to date has examined the behavioural pathway through which children with more avid appetites gain weight. **Chapter 8** aims to explore for the first time the inter-relationships between appetite, eating patterns and adiposity in early life.

2.1.6 The continuity and stability of dietary intake and appetite from early to mid-childhood

Dietary intake during the early years appears to influence longer-term food choice and eating behaviours as nutrient intakes and dietary patterns have previously shown continuity from early to middle childhood (Nicklas et al. 1991; Singer et al. 1995; Northstone & Emmett 2008). Previous research, however, has tended to focus on how *what* children eat tracks over time, rather than *how* they eat. **Chapter 9** aims to explore not only the stability and continuity of dietary intake from early to mid-childhood, but also the stability and continuity of eating patterns (meal size and frequency) as the latter has never been explored. Appetitive traits have previously been shown to be relatively stable during mid to late childhood and **Chapter 9** will explore the tracking of appetite in a young sample of children from 16 months to seven years of age.

2.2 Samples

This thesis will predominantly use data from a large population-based birth cohort of twins; Gemini – Health and Development in Twins, set up in 2007. Details about the sampling methods and measures used within Gemini are described in detail in **Chapter 3**. In addition to the Gemini sample, data from the National Diet and Nutrition Survey (NDNS) rolling programme (2008-2012) will be used for comparison, as will data from the Diet and Nutrition Survey for Infants and Young Children (DNSIYC) conducted in 2011.

2.3 My contributions to the research included in this thesis

The Gemini study was set up in 2007 and as my thesis began in 2012 I was not involved in the initial recruitment or set-up of the study. Nor was I involved in the early data collection such as data collected using the Child Eating Behaviour Questionnaire (CEBQ) when the twins were 16 months old, or the diet diary data collected in 2008-9 when the twins were 21 months old. However, I manually coded every eating and drinking occasion in the dietary dataset (53,000 rows of data) and computed nutrient and energy intake information for each child (n= 2336). I organised the second round of data collected using the CEBQ and diet diaries in a subset of families at seven years of age which involved adapting the 21 month diet diaries and portion guides to ensure they were suitable for children aged seven years of age. I coordinated the delivery of these measures to 1900 families still active within the Gemini study, liaised with the Human Nutrition Research (HNR) Unit, Cambridge to negotiate the cost of coding the dietary data, and I kept an electronic record of all measures received from parents. I entered all CEBQ data into SPSS and I spent some time at the HNR unit to familiarise myself with how the diary records are input into the dietary assessment software. I also coded the second dietary dataset in the same way as the first to enable comparisons to be made.

I designed an interview protocol in order to conduct telephone interviews with a sample of families (n= 35) when the twins were six years of age. I coordinated and conducted all 35 interviews, carried out the content analysis of these interviews and the inter-rater reliability check.

Throughout my research I have been heavily involved in running the Gemini study and have carried out a number of administrative tasks. I have been responsible for responding to all email correspondence received from Gemini families and this can often be requests for weighing scales or height charts which I will then send to families in the post. I have also received height and weight measurements every three months via email and entered these into the Gemini database. Over the past four years I have also ordered and sent birthday cards every day from March-December to the twins in the sample as a means of maintaining the sample.

I came up with my overall thesis aim and I designed all the analyses that allow me to achieve my research aims. All the analyses were performed by me unless indicated by footnotes.

CHAPTER 3: SAMPLING AND METHODOLOGY

3.1 Gemini – Health and Development in Twins

The Gemini study was set up by Professor Jane Wardle at the Health Behaviour Research Centre in the Department of Epidemiology and Public Health, University College London, in 2007. It is a population based birth cohort of young twins in England and Wales, designed to assess the genetic and environmental influences on growth in early childhood. The study focuses on children's appetite, and the food and activity environments, with three primary aims: i) to enhance understanding of the genetic and environmental influences on weight gain; (ii) to identify modifiable determinants of excessive weight gain in early childhood, and; (iii) to create a rich resource of data on early childhood exposures that can be used to assess the determinants of long-term health (van Jaarsveld et al., 2010). The Gemini study allows exploration of the role of appetite (the appetitive characteristics that determine actual eating behaviour), diet (types of foods and drinks consumed) and eating patterns (the size and frequency of eating occasions) in weight gain. Identifying the role of appetitive traits in eating behaviour, and subsequent weight gain, could make an important contribution to explaining variation in children's weight.

3.2 Methods

3.2.1 Study population and recruitment

Recruitment of families in Gemini was assisted by the Office for National Statistics (ONS). In January 2008 the ONS asked all families with twins born in England and Wales between March and December 2007 (*N*= 6754) if their contact details could be passed to the Gemini research team. 3435 families agreed and were sent an initial invitation letter **(Appendix 3.1)**. A few weeks later they were sent a baseline questionnaire letter **(Appendix 3.2)**, the baseline questionnaires **(Appendix 3.3)**, information leaflet **(Appendix 3.4)** with details of the Gemini study, and a consent form **(Appendix 3.5)** between February and July 2008. 2402 families completed the baseline questionnaire and constitute the Gemini sample, which represents 36% of those initially contacted by ONS, and 70% of families who agreed to be contacted by the Gemini research team **(Figure 3.1)**. This was considered a reasonable response rate given that the twins were less than one year old at initial contact, and the baseline questionnaire was lengthy.

3.2.1.1 Non-response analyses

The ONS provided the Gemini study team with details on response rates for all families contacted in 2007. Non-response analyses were conducted and explored in relation to the month of the twins' birth, the mother's age at the twins' birth, and the region of residence. Pearson's chi-square tests[a] assessed differences between the target population and the Gemini cohort (Van Jaarsveld et al. 2010). **Table 3.1** shows the ONS information for the target population and the families who responded (those who make up the Gemini sample). Response rates were slightly higher for families in which the twins were born at the end of 2007 (November) and were lower in March and April. Overall rates by month of twins' birth ranged from 32% - 42% ($\chi 2=21.187$ (9 df), $p= 0.012$). Response rates ranged from 23% to 45% by mother's age at the twins' birth ($\chi 2=151.447$ (5 df), $p< 0.001$), with higher response in 30-34 year olds and lower response rates in mothers aged 20-24 years or over 40 years. **Figure 3.2** shows the distribution of the Gemini families across England and Wales. Response rates were higher in the South East of England, the East of England, the Midlands, and the South West of England and were the lowest in London. Response rates by region ranged from 19% to 45% ($\chi 2=241.261$ (9 df), $p< 0.001$).

[a] This analysis was conducted by Dr Cornelia HM van Jaarsveld

Table 3.1. Non-response analyses comparing the target population with participating Gemini families (Van Jaarsveld et al. 2010)

	Target population[a] (*n*= 6754)	Gemini Sample (*n*= 2402 families)	Response rate[c] (%)
Month of twins' birth[b]			
March	766	245	32[d]
April	720	238	33[d]
May	776	277	36
June	773	282	36
July	861	296	34
August	677	244	36
September	718	252	35
October	729	261	36
November	616	261	42[e]
December	118	46	39
Total	**6754**	**2402**	**100**
Mother's age at twins' birth			
Under 20 years	82	25	30
20-24 years	594	160	27[d]
25-29 years	1345	446	33
30-34 years	1993	900	45[e]
35-39 years	1995	714	36
Over 40 years	667	151	23[d]
Not known	78	6	-
Total	**6754**	**2402**	**100**
Region of residence			
London	1209	231	19[d]
South East	1057	468	44[e]
North West	824	275	33
West Midlands	712	228	32
East of England	699	317	45
Yorkshire and the Humber	634	222	35

East Midlands	468	194	41[e]
South West	567	255	45[e]
Wales	320	117	37
North East	262	94	36
Not known	2	1	-
Total	**6754**	**2402**	**100**

Abbreviations: %, percentage

[a] The target population consisted of all families with registered twin births in England or Wales between March and December 2007. They were contacted by the Office for National Statistics (ONS) and asked if they were willing to be contacted by the Gemini research team.

[b] All twins were born in 2007

[c] The mean response rate among the three categories was 36%

[d] Lower response rate than the mean of 36%

[e] Higher response rate than the mean of 36%

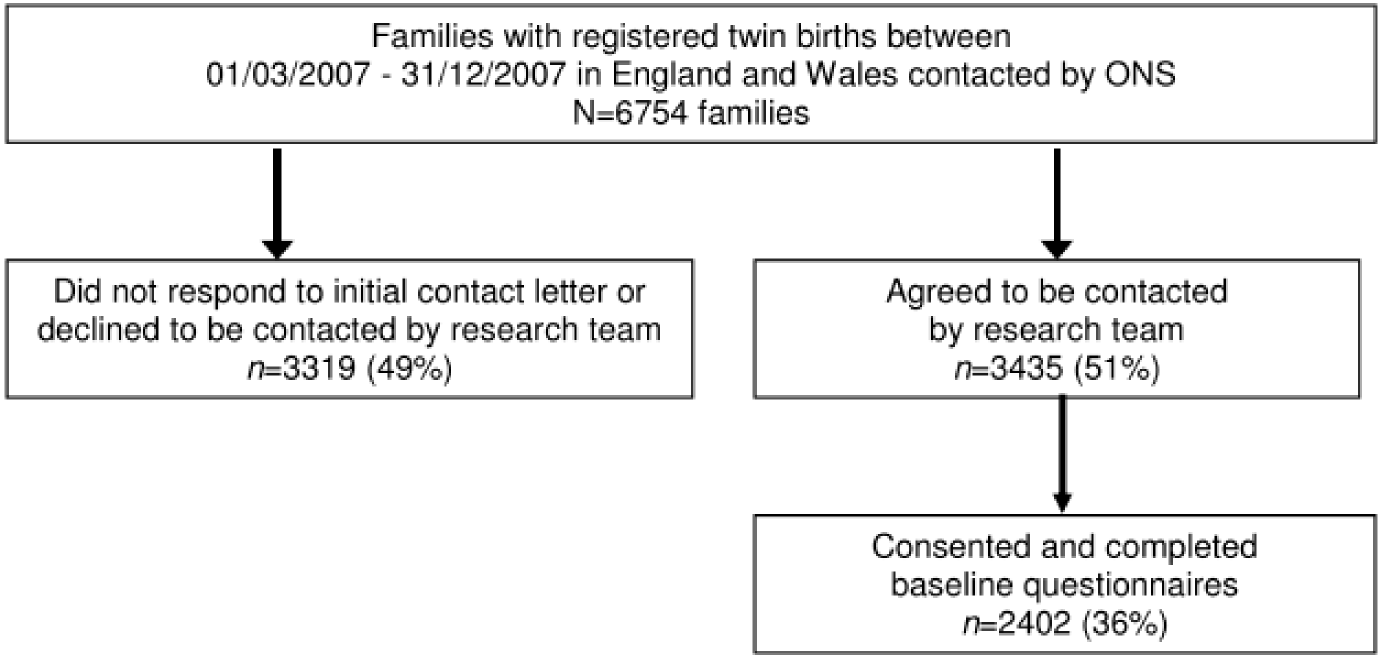
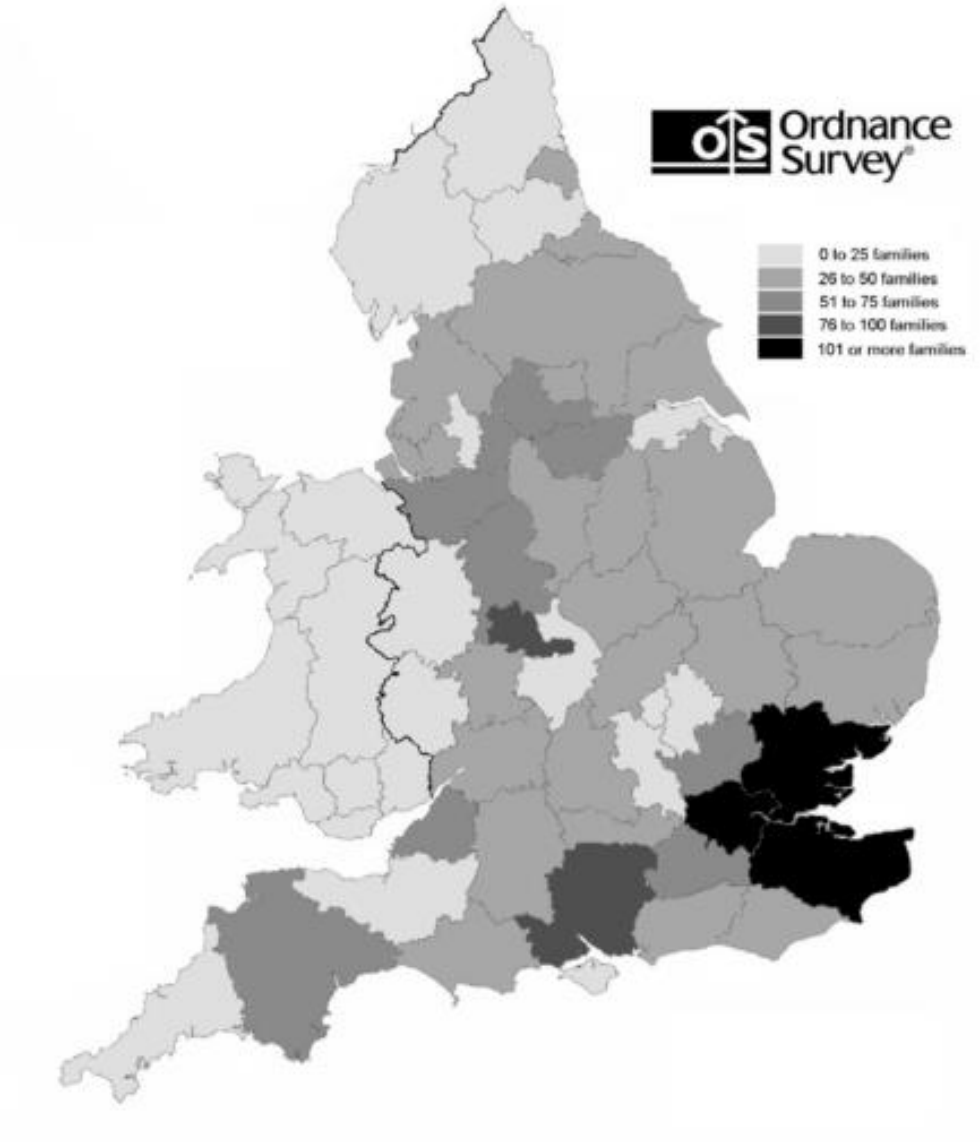


Figure 3.1. Flow diagram of recruitment of Gemini families

Figure 3.2 Map of England and Wales showing the distribution of participating Gemini families



3.2.2 Data collection

Data within the Gemini study is collected using parent reports. Throughout the study parents have been asked to complete questionnaires, diet diaries, collect DNA samples from the twins using cheek swabs, and take part in telephone interviews. All parents have been provided with height charts and Tanita digital weighing scales to record their twins' heights and weights at regular three-month intervals. An overview of the measures and assessment points in Gemini are shown in **Table 3.2.** The current thesis uses data from questionnaires completed by parents at baseline, questionnaires completed when the twins were 16 months of age, and diet diaries completed at 21 months. In addition, I conducted telephone interviews with a sub-sample of parents when the twins were six years old, and I developed a second diet diary that was completed by parents when the twins were approximately seven years old, along with a questionnaire about the twins' appetites. The measures used in this thesis were either based on validated questionnaires or were designed for Gemini and then piloted in parents of young children (singletons and twins). The various measures are described in more detail below.

Table 3.2. Overview of the measures and assessment points in Gemini (adapted from van Jaarsveld et al 2010)

	Child age (months)									
	8	**15**	**20**	**24**	**30**	**42**	**48**	**60**	**76**	**84**
Child variables										
Anthropometrics	X	X		X		X	X	X		
Appetite	X	X						X		X
Food preferences, sensory experiences		X				X				
Activity behaviour	X	X					X	X		
Activity preferences							X			
TV watching		X					X	X		
Sleep behaviour		X					X	X		X
Birth complications/medical conditions	X	X		X				X		
Introduction of solid foods	X	X								
Three-day diet diary			X							X
Temperament								X		
DNA collection using cheek swab					X					
Formula feeding interviews									X	
Allergies										X
Family variables										
Parental feeding style	X	X						X		
Demographics, anthropometrics, health behaviours of both parents	X			X				X		
Parental eating behaviour				X						
Parental activity behaviour				X						
Parental sleep behaviour								X		
Parental diet								X		
Parental illnesses/medical conditions	X							X		
Environmental confusion/‘chaos’								X		
Home environment							X			

3.2.2.1 Socio-demographic information

The baseline questionnaire, which was available in paper form and online (9.7% of families completed it online), was used to obtain the majority of socio-demographic information. The parent completing the questionnaire was asked to state their relationship to the twins and then provided details about both themselves and their twins. They reported the sex, and date of birth of the children; details of the mother's pregnancy and birth, anthropometric information, health behaviours, ethnicity and socio-demographic information were also requested. In addition, the twins' anthropometrics from birth were obtained, as were details of their early appetite and feeding behaviour, food preferences, activity behaviour and parents' feeding styles. The zygosity of the twins was classified in a number of ways. All opposite-sex twins were classified as dizygotic (DZ). The zygosity of same-sex twin pairs (*n*= 1586 pairs) was classified based on results from a 20-item zygosity questionnaire (Price et al. 2000) that was completed by 934 parents at baseline and again when the twins were on average 29 months old. In addition to the questionnaire, confirmatory DNA testing in a sub-sample of 81 pairs was conducted. Genotyping and questionnaire classification matched in all cases. A total of 749 twin pairs (31%) were classified as MZ and 1616 (67%) twin pairs were classified as DZ (including 816 opposite sex DZ twins), based on the questionnaire and DNA results. Zygosity could not be established for 37 twin pairs (1.5%) as questionnaire results were unclear and no DNA was provided.

3.2.2.1.1 Age

At baseline we asked parents to report the number of weeks the mother had been pregnant at the time of delivery and this was used as an estimate of gestational age. The age of the twins upon completion of all measures used in this thesis was obtained using their date of birth and the date on which each of the measures was completed.

3.2.2.1.2 Socio-economic status

Two indices of socio-economic status were derived for use in this thesis: maternal educational attainment, and the ONS National Statistic Socio-economic Classification (NS-SEC) index based on occupation (Office for National Statistics 2005). Parents were asked to rate the mother's highest educational qualification (‘No qualifications’, ‘CSE, GCSE or O Level’, ‘Vocational qualification (GNVQ, BTEC)’, ‘A or AS Level’, ‘Higher National Certificate (HNC) or Diploma (HND)’, ‘Undergraduate degree’, ‘Postgraduate qualification (Masters, PhD)’, ‘Other, please describe’); and these were then dichotomised into lower (no university education) and higher (university level education).

Parents stated their occupation and their partner’s occupation, and using the household NS-SEC was derived. Occupations fitted into one of eight NS-SEC categories (higher and lower managerial and professional occupations, intermediate occupations, small employers and own account workers, lower supervisory and technical occupations, (semi) routine occupations, routine occupations, never worked or long-term unemployed). Each category was assigned a corresponding score; higher scores representing higher SES. The parent from each household with the highest socio-economic status (SES) was selected as the household reference. In most cases this was the partner (41%), but in 29% of families it was the mother, and it was equal in 18% of families. In 12% of cases data were missing or the mother did not have a partner so the person that did have SES data was assigned as household reference person. Occupations were grouped into three categories: higher SES (higher and lower managerial and professional occupations), intermediate SES (intermediate occupations, small employers and own account workers) and lower SES (lower supervisory and technical occupations, (semi)routine occupations, routine occupation, never worked or were long-term unemployed).

3.2.2.1.3 Ethnicity

Parents reported their ethnicity and that of their partner by selecting from a pre-defined list (‘White British’, ‘White Irish’, ‘Other White background’, ‘Caribbean’, ‘African’, ‘Other black background’, ‘Indian’, ‘Pakistani’, ‘Bangladeshi’, ‘Other Asian background’, ‘White and Black Caribbean’, ‘White and black African’, ‘White and Asian’, ‘Other mixed background’, ‘Chinese’, ‘Any other’). These categories were taken from the ONS interim standard classifications for presenting ethnic and national groups data. Twin ethnicity was classified using the parents’ ethnicity: if both parents selected the same ethnicity category the twins were also classified as that category; if parents selected different categories the twins were classified as 'mixed ethnicity'; if one parent's ethnicity information was missing, twin ethnicity was classified as the other parent's ethnicity group. The twins' ethnicity was then dichotomised into 'white' and 'non-white'.

3.2.2.1.4 Representativeness of the Gemini sample

The representativeness of the Gemini cohort was assessed by comparing the socio-demographic characteristics of the sample measured in the baseline questionnaire with that of the wider population using national statistics published by ONS[b]. **Table 3.3** shows the characteristics of the twins in the Gemini sample and those of national twin statistics. Slight differences can be observed but in summary the Gemini sample is representative of UK twins when compared with national twin statistics on sex, gestational age, zygosity and birth weight (van Jaarsveld et al. 2010). Parents provided informed consent on behalf of their twins' to participate in the study, and ethical approval was obtained from the University College London Committee for the Ethics of Non-National Health Service Human Research.

Table 3.4 compares the baseline characteristics of parents in Gemini with the national population. There is an over-representation of parents of white ethnicity in Gemini, and parents tended to be older at the twins' birth (Office for National Statistics 2006). Gemini parents also had lower BMIs (Craig & Shelton 2008), higher educational attainment (Department for Innovation Universities and Skills 2008) and higher NS-SEC classifications (Office for National Statistics 2003) than the national population.

[b] These analyses were conducted by Cornelia HM van Jaarsveld

Table 3.3. Characteristics of twins in the Gemini sample and national twin statistics

	Gemini sample (*n*= 2402 families; *n*= 4804 twins)	**National statistics**[a] (%)
Age, mean (SD)[b]	8.18 (2.18)	-
Gestational age (wks), mean (SD)	36.20 (2.48)	37
Birth weight (kg), mean (SD)	2.46 (0.54)	2.50
Zygosity of twin pairs[c], N (%)		
MZM	352 (14.7)	-[c]
DZM	409 (17.0)	
MZF	397 (16.6)	
DZF	391 (16.3)	
DZO	816 (34.0)	
Unknown	37 (1.5)	
Sex of twin pairs, N (%)		
Male	785 (32.7)	32.1
Female	801 (33.3)	32.8
Opposite sex	816 (34.0)	35.1
Sex of infants, N (%)		
Male	2386 (49.7)	-[c]
Female	2418 (50.3)	-[c]
Pre-term (<37 wks), N (%)	1045 (43.5)	40

Abbreviations: SD, standard deviation; wks, weeks; MZM, monozygotic male twin pairs; DZM, dizygotic male twin pairs; MZF,monozygotic female twin pairs; DZF, dizygotic female twin pairs; DZO, dizygotic opposite sex twin pairs; %, percentage

[a] Office for National Statistics (2006). Birth statistics Series FM1 no.35. Review of the Registrar General on births and patterns of family building in England and Wales. Newport. (Numbers are for twin births in 2006). 2006 national statistics are presented as the Gemini twins were born around this time.

[b] Twins' age at the time the baseline questionnaire was completed.

[c] ONS has not published national statistics on these variables.

Table 3.4. Characteristics of parents participating in Gemini compared to National statistics

	Total Gemini Sample (*n*= 2402 families; *n*= 4804 twins)	**National statistics** (%)
Mother's ethnicity, N (%)		
White	2089 (87.0)	78.1[a]
Non-white	311 (12.9)	21.9
Not known	2 (0.1)	
Father's ethnicity, N (%)		
White	1988 (87.8)	72.6[a]
Non-white	275 (11.4)	27.4
Not known	139 (5.8)	
Age at twins' birth (years), mean (SD)		
Mother	33.6 (5.2)	29.5[a]
Father	36.4 (6.2)	-
BMI[b] (kg/m²), mean (SD)		
Mother	25.1 (4.8)	26.8[c]
Father	26.4 (3.9)	27.1
Marital status, N (%)		
Married or cohabiting	2276 (94.8)	60[d]
Divorced or separated	31 (1.3)	10
Single	93 (3.9)	20
Not known	2 (0.1)	
Maternal education, N (%)		
Low/intermediate	1150 (47.9)	69.7[e]
High	1252 (52.1)	30.3
Paternal education, N (%)		
Low/intermediate	1969 (82.0)	69.7[e]
High	433 (18.0)	30.3
NS-SEC classification, N (%)		
Low	472 (19.7)	33[f]
Intermediate	407 (16.9)	18
High	1515 (63.1)	49
Not known	8 (0.3)	

Abbreviations: %, percentage; SD, standard deviation; NS-SEC, National Statistics Socio-economic Classification

[a] Office for National Statistics (2006). ONS Population report for England and Wales. Statistics correspond to parents with live births in 2006.

[b] BMI for parents in the Gemini sample was calculated from self-reported weight and height

[c] Health Survey for England 2007. (2008). Volume 1. Health lifestyles: knowledge, attitudes and behaviour. Ed R. Craig & N. Shelton. The health and social care Information Centre.

[d] Office for National Statistics (2008). General Household Survey 2007. Data for Great Britain in individuals 16 years and over.

[e] Department for Innovation, Universities and Skills (2008). The level of highest qualification held by adults: England 2007. Education levels have been dichotomised into low/intermediate (no qualifications; GCSEs, an Intermediate GNVQ, two AS-levels, NVQs at levels 1 & 2, BTEC general certificates, YT certificates, other RSA certificates or other City and Guilds certificates; 2 A-Levels, 4 AS-Levels, an advanced GNVQ or NVQ level 3) and high (foundation or first degrees, recognized degree-level professional qualifications, NVQ level 4, teaching or nursing qualifications, HE diploma, HNC/HND or equivalent; post-graduate level qualifications and NVQ level 5).

[f] Office for National Statistics (2003). Socio-economic classification of working-age population, summer 2003: Regional Trends 38. Categories were grouped into low (lower supervisory and technical occupations, (semi)routine occupations, never worked and long-term unemployed), intermediate (intermediate occupations, small employers and own account workers) and higher (higher and lower managerial and professional occupations).

3.2.2.2 Appetitive traits

Parents completed the Child Eating Behaviour Questionnaire (CEBQ) **(Appendix 1.2)** when the twins were approximately 16 months old (mean= 15.71; SD= 1.05) and again when the twins were approximately seven years old (mean= 7.2; SD= 0.2). As described in **Chapter 1**, the CEBQ is a parent-report, psychometric measure of a range of paediatric eating behaviours that have been linked with weight. The measure has good reliability and internal consistency (Cronbach's alphas ranging from 0.74 to 0.91) (Wardle et al. 2001), and has been validated against behavioural measures of food intake (Carnell & Wardle 2007). It includes two 'food approach' behaviours; 'Food Responsiveness' (FR), 'Enjoyment of Food' (EF), three 'food avoidance' behaviours; 'Satiety Responsiveness' (SR), 'Slowness in Eating' (SE) and 'Food Fussiness' (FF). Two scales measure eating in response emotions; 'Emotional Overeating', and 'Emotional Under-eating'. There is also one drinking approach trait 'Desire to drink'. All items are scored on a five-point Likert scale as 'never', 'rarely', 'sometimes', 'often', or 'always'. Mean scores were calculated for each subscale (range: 1–5) if at least 65% of items were completed (i.e. 2/3, 3/4, 3/5, or 4/6 items). Higher scores on the FR, EF EO and DD subscales represent greater interest in food and a more avid appetite, and higher scores on the SR, SE, EUE and FF represent greater food avoidance, and lower appetite avidity.

The measure used at 16 months of age within the Gemini sample (**Appendix 1.3**) was modified to be age appropriate for toddlers (CEBQ-T). In particular, it included only six of the original eight subscales: EF (4 items, e.g. "My child enjoys eating"), FR (4 items, e.g. "My child is always asking for food"), EO (3 items, e.g. "My child eats more when anxious"), SR (5 items, e.g. "My child gets full up easily") , SE (4 items, e.g. "My child takes more than 30 minutes to finish a meal"), and FF (7 items e.g. "My child refuses new foods at first"). The DD and EUE subscales were not included because pilot work with mothers indicated that toddlers did not exhibit these behaviours. Also, with regards to the DD scale, it was expected that some children at 16 months of age might still drink milk as part of a meal, while for others it is solely a drink, so this scale would be confusing. This thesis uses all six subscales from the CEBQ-T, with a predominant focus on SR and FR.

At seven years of age, five of the eight CEBQ subscales were included: EF, FR, SE, SR, FF (**Appendix 3.6**). Three CEBQ scales were omitted (EOE, EUE, DD) to make the questionnaire shorter and less time consuming to complete in order to maximise the response rate within the cohort.

3.2.2.3 Anthropometrics

Defining overweight and obesity in children is complex because Body Mass Index (BMI), a ratio of weight to the square of height (calculated using the equation: weight (kg)/height $(m)^2$), varies with development (age), sex and ethnicity. Therefore adult cut-offs (overweight= BMI>25kg/m^2, and obese= BMI>30kg/m^2) cannot be used. Instead, age-, sex- and population-specific cut-offs are applied, using reference data. Weight SDS were used in the current thesis to determine whether children were growing at a faster or slower rate than the population mean. A weight SDS of zero indicates average weight, a weight SDS greater than zero indicates higher weight, and a weight SDS less than zero indicates lower weight, compared to the reference population. These are calculated using British 1990 growth reference data (Cole et al. 1995) with the LMS Growth macro for Microsoft Excel (Cole 2008). The reference data was developed with the use of 12 surveys conducted between 1978 and 1994 in which 32,222 measurements were taken of children aged between 0-20 years to represent the distribution among the population. Centiles are used to indicate weight status which take into account the child's age and sex. At a population level, children with a weight or BMI below the 2^{nd} centile (SDS <2.00) are considered underweight, those at or above the 85^{th} centile (SDS≥1.04) are considered overweight, and those above the 95^{th} centile (SDS>2.00) are considered obese. At a population level, children are classified as healthy weight if they fall between the 2^{nd} and 85^{th} centile.

In Gemini, the baseline questionnaire asked parents to report birth weight and subsequent weights in the first few months of life for both twins, up to the date the baseline questionnaire was completed. Weights were taken from the child's 'red book' – a personal health record routinely kept until two years of age, and parents were asked to photocopy the relevant pages or write the measurements in the questionnaire. These weights were measured by health professionals. From two years of age parents were sent weighing scales and asked to weigh their twins every three months. They were also sent height charts with instructions (**Appendix 3.7**) on how to measure their twins' height every three months. The Gemini team set up a website for parents to upload measurements (http://www.geministudy.co.uk/gemweight/) and were sent email and postcard reminders (from 18 months) to remind them to take these measurements every three months.

Weights were recorded to the nearest pound or tenth of a kilogram and heights to the nearest centimetre or inch. All imperial data were later converted to metric, and in cases where information was provided in both measurement units the metric units were used. Birth weights less than half a kilogram or greater than five kilograms were deemed to be misreported and were coded as missing. Birth weight SDS was calculated for each child. Data were cleaned[c] to ensure impossible values were removed, and individual graphs (for all 2402 twin pairs) were checked for the weights and heights of all co-twins to check for the accuracy of each child's values (i.e. to ensure the twins' values had not been switched). All individual graphs were examined and any outliers checked with original questionnaires for data entry errors and corrected where possible; remaining measurements which were not matching the individual's growth curve were recoded to missing.

3.2.2.3.1 Adiposity aged two years

Adiposity at two years of age was indexed using weight and weight SDS. Weight in kilograms reported at 24 months was the preferred weight measurement for two year weight. If this was unavailable, weight at 27 months was used, or 21 months if neither 24 months nor 27 months weights were available. This was because unfortunately weight data were not collected at the time of diary completion, and also all children in the UK have a two year health assessment by a health visitor so considerably more weight data were available at this age (*n*= 1711) compared with 21

[c] The data cleaning was conducted by Cornelia HM van Jaarsveld

months (n= 960). Intervals (21, 24 and 27 months) were used in order to increase the sample size.

In the current thesis weight SDS was used to classify weight status at two years of age, relative to the UK population mean in 1990, for the child's age, sex, and gestational age. If children had a weight SDS≥1.04 (at or above the 85th percentile) they were classified as overweight, and if they had a weight SDS<1.04 (below or equal to the 85th percentile) they were classified as healthy weight.

3.2.2.3.2 Growth up to five years of age

Weight gain (g/week) during early childhood was explored using all available weight measurements for each child from two to five years in a longitudinal model. Raw scores (weight in grams) rather than weight SDS were used because we were characterising growth per se rather than relative body size at any one time. Had we used weight SDS we would be comparing each child's weight to a different sample from which the age and standard deviation were determined. The reference data (UK population mean in 1990) (Cole et al. 1995) were not drawn up using longitudinal data for a set of children beginning at birth and following them up to age 18, rather it used different samples of children for each of the different ages.

Weight status at five years was indexed using BMI SDS. Weights and heights reported at 60 months were preferred. If this was missing then data from 63 months were used, or 57 months if neither 60 months nor 63 months weights/heights were available. Inevitably attrition occurred over time with the prospective cohort so there were a reduced number of children with five year weight and height measurements (n= 1552). BMI and BMI SDS at five years, were computed using LMS Growth. Weight status (healthy weight or overweight) was derived using the same methods used at two years of age. A BMI SDS≥1.04 was deemed to be overweight, and healthy weight a BMI SDS<1.04.

3.2.2.4 Dietary intake (21 months of age)

Unweighed diet diaries **(Appendix 3.8)** were sent to all Gemini families (n= 2402) between November 2008 and August 2009. Parents were sent a letter (**Appendix 3.9)** and a portion guide (**Appendix 3.10)** which advised parents on how to accurately estimate and record all food and drinks consumed by each twin for three days (any two weekdays and one weekend day). If children were in childcare the care-giver was asked to complete the diary.

3.2.2.4.1 Portion guide

The portion guide was adapted from the preschool (age 18 months to four years) food atlas (Foster et al. 2010a; Foster & Adamson 2012) developed using data collected during the National Diet and Nutrition Survey for children aged 18 months to four years (Gregory et al. 1995). It contains the most commonly consumed food items (*n*= 104) by young children and provides a range of age appropriate portion sizes for food served and food leftover. For foods that do not come in predetermined amounts such as pasta, baked beans and cereals, there are seven photographs to represent the 5th to 95th centile of food weights served, presented as equal increments on a log scale. There are also seven photographs to represent from the 5th centile of food portion served to the smallest presentable portion for estimation of the amount leftover, based on the fact that not all children, and especially young children, consume all of the food that is served to them. There are fewer photographs for items that come in predetermined amounts such as bread rolls and biscuits.

The Gemini portion guide (**Appendix 3.10)** included 18 of the food items in the food atlas and these were selected on the basis that they were similar foods to those used in the portion guides for adults in the NDNS (Hoare et al. 2004), EPIC-Norfolk (Riboli et al. 2002) and the National Survey of Health and Development (Wadsworth et al. 2006). Additional food items were included in the guide in order to represent the most common foods eaten by young children (aged 18 months to four years) in the NDNS (Wrieden et al. 2008). Due to limited space, not all food items included in the pre-school food atlas could be incorporated. However, the portion guide can be used for foods similar to those depicted in the photos and therefore allows many more foods to be described. In order to aid parents, items were listed (e.g. 'pizza') along with examples of how to describe the item and how it was prepared (e.g. 'thin base or deep pan or French bread; topping; brand name and type'). In addition there were examples of how to report the portion size (e.g. 'weight of whole pizza and/or slice e.g. 1/8 of a 190g pizza. Estimate size of pizza with photo 19').

The first five of the seven photographs of food weights served in the pre-school food atlas were used in the Gemini portion guide (listed as A, B, C, D, E). The reason for selecting the first five was that the Gemini twins were 21 months old, and the seven photographs in the atlas are based on portions for children 18 months to four years. Parents were asked to select the photograph that corresponded to the food item (numbered one to 18) and portion size (listed A-E) that best represented the amount *eaten* by each child, for example 4A would represent the smallest portion of cake in the guide. The diet diary itself also contained an example of a day's entries to assist parents with completion.

3.2.2.4.2 Diet diary

Diet diaries were piloted with 38 mothers of twins who were not part of the Gemini cohort itself but were recruited via the Twins and Multiple Births Association (TAMBA); a UK twin and triplets charity. Mothers were emailed to confirm that they were willing to pilot the diary (**Appendix 3.11**) and were then sent the diary along with a letter (**Appendix 3.12**) explaining what was being asked of them. A follow-up phone call was arranged to obtain feedback on how they found completing the diary (**Appendix 3.13**). The pilot diary was amended slightly following the piloting process, for example set time slots such as 6am to 9am, and 9am to 12pm were removed so that parents were free to record the timing of the eating or drinking occasion. Diet diaries were completed by 1357 families (56.5% of the baseline sample) when the twins were approximately 21 months old. 61 families completed one day, 128 families completed two days, and 1168 families completed three days of entries.

In order to minimise variability in intake on a day to day basis, only children with three days of complete diary entries (*n*= 1168 families; *n*= 2336 children) have been included in analyses within this thesis. Non-response analyses compared the characteristics of the twins with three day diet diary data at 21 months of age (*n*= 2336) compared with the full Gemini sample (*n*= 4804) (**Table 3.5)**. Pearson's chi-square tests assessed sex, ethnicity and maternal education differences between responders and non-responders. Independent samples t-tests assessed mean differences in birth weight SDS and gestational age across the two groups.

Children had a mean age of 20.64 months (SD= 1.10) at the time of diet diary completion. In comparison to the full Gemini sample the diet diary sample contained more girls (51.5%) than boys, a higher proportion of families of white ethnicity and higher educational status and a lower proportion of infants were breast fed in the first three months.

Table 3.5. Diet diary sample characteristics (21 months of age)

	Diet diary sample (*n*= 1168 families; *n*= 2336 twins)	**Full Gemini sample** (*n*= 2402 families; *n*= 4804 twins)	***p*-value**[a]
Sex, N (%)			0.86
Boys	1157 (49.5)	2386 (49.7)	
Girls	1179 (51.5)	2418 (50.3)	
Ethnicity, N (%)			<0.001
White	2222 (95.1)	4178 (87.0)	
Non-white	106 (4.9)	626 (13.0)	
Maternal education[b], N (%)			<0.001
Low/intermediate	1194 (51.1)	2792 (58.1)	
High	1142 (48.9)	2012 (41.9)	
Age at diary completion (m), mean (SD)	20.64 (1.10)	20.71 (1.16)	<0.001
Weight at birth (kg), mean (SD)	2.46 (0.54)	2.46 (0.54)	0.64
Weight SDS at birth (kg), mean (SD)	-0.54 (0.93)	-0.56 (0.95)	0.30
Gestational age (wk), mean (SD)	36.17 (2.49)	36.20 (2.48)	0.38
Feeding method (0-3 months) (n(%)			<0.001
Breast-fed infants	1468 (62.8)	3486 (73.1)	
Bottle-fed infants	868 (37.2)	1090 (22.8)	

Abbreviations: %, percentage; m, months; SD, standard deviation; kg, kilograms; wk, weeks

[a] P-value for difference between the 21 month diet diary sample and full Gemini sample on listed characteristics

[b] Maternal educational attainment was dichotomized into lower (no university level education) and higher (university education).

[C] The proportion of infants breast fed in the first three months from birth was obtained with the question "which feeding method did you use in the first 3 months?" with response options ranging from 1=entirely breast feeding to 6=entirely bottle feeding. Categories 1-5 were classified as 'breast fed' and category 6 as 'bottle-fed'.

3.2.2.4.3 Coding of dietary data

All diaries were sent to the Medical Research Council Human Nutrition Research (HNR) in Cambridge and were quality checked. All diaries were deemed to contain enough detail for coding. Coding was carried out using Diet In Nutrients Out (DINO), an integrated system for dietary data entry and nutrient analysis of food diaries developed in 2005 at HNR (Fitt et al. 2014). DINO has two platforms: i) an interface for the dietary data entry which enables entry of the dietary assessment record, and ii) food composition tables which allow nutrient analysis for calculation of nutrient intakes. The data entry interface contains functions to search for foods and provide details such as brand names and portion size data. If there is not an exact match to a food item listed in a diary, DINO will provide a 'substitute food' which provides a close nutritional match. There are also default items; for example, if 'cheese' is reported but the brand or type of cheese is not stated then 'cheddar cheese' will be the default.

The food composition data used in DINO are based on the UK food composition tables (Food Standards Agency 2002) and DINO is able to quantify foods eaten as part of composite items (those that contain two or more components in varying proportions, such as lasagne) as well as discrete portions, such as an apple. Composite foods are disaggregated into main food components (fruit, vegetables, meat, fish and cheese) (Fitt et al. 2010) and these are then further divided into sub-categories, for example meat is divided into beef, pork, lamb, etc. By disaggregating composite foods into their individual food components a more complete estimate of intake at the individual food level can be obtained.

Using the portion sizes depicted in the portion guide photographs, weights of foods were ascertained; from these, the average intakes of energy and macro- and micronutrients from foods were estimated. Portion size conversion factors were applied to enable a food in the portion guide photo to be used to represent the volume of other similar foods. This allowed the weight of an alternative food to be reflected when the density differed from that depicted in the photo, for example if a child had 'Coco pops' for their cereal rather than the 'Cornflakes' shown in the portion guide. If a food item was stated but the portion size was not reported by parents, coders at HNR used existing DINO portions which were standardised portion sizes for children aged between 18 months and four years. They correspond to the mid-point of the five photographs used in the portion guides (Photograph C).

3.2.2.4.4 Deriving dietary variables for analysis

The 21 month diet diary data consisted of 193,647 entries (food and drink items) for the sample as a whole. All entries occurring at the same time point, on the same day for each twin were combined into a ‘consumption occasion’. This left 52,908 consumption occasions which I then manually coded as either eating or drinking occasions. Eating occasions were defined as occasions in which food was consumed at a unique clock time (to the nearest minute on each day) including drinks consumed at the same time, regardless of the amount or type of food items reported or time of day. Drinking occasions were defined as any occasion in which solely drinks (no food) were consumed. Formula milk and breast milk were assigned their own codes in order to explore these as distinct categories in their own right.

3.2.2.4.4.1 Devising a coding system for classifying food and drinks

At the time of diary completion parents were asked to classify items within a consumption occasion as a snack or meal. Interestingly some parents also created another category of ‘drinks’ and in addition there were items that were not classified by parents (‘unspecified’). All combinations of parent coding for items within each consumption occasion were computed (**Table 3.6)** and explored in more detail to determine how parents seemed to be coding meals and snacks. As an example, ‘meals’ refers to occasions in which all items within an occasion were classified as a meal by parents. ‘Meals and not specified’ on the other hand were occasions in which some items were classified as meal items but others were not classified. The majority of the time parents seemed clear on what constituted a snack, a meal and a drink as almost 80% of consumption occasions were defined as one of these. There were however a large number of occasions (*n*= 7456) which were unspecified by parents, presumably either because they simply omitted to complete this part of the diary, or they were unclear on what to code the items. Interestingly, some occasions had items in the occasion classified as a meal and other items classified as a snack (‘meals and snacks’; *n*= 1118 occasions) which suggests that these parents were using a ‘what’ approach to define a meal or snack, rather than a ‘when’ approach because in these instances the foods were consumed at the same time point but some were classed as meals and some as snacks.

There is clearly ambiguity surrounding what is a meal and what is a snack. Using parents’ definitions would have led to a large amount of missing data and I therefore decided not to use the parents’ definitions. Instead I developed a coding frame, adapted from a classification system by MacDiarmid et al (2009), to code occasions as meals, snacks, or drinks (**Table 3.7**) (Macdiarmid et al. 2009). However, there were a large number of eating occasions in which queries arose (*n*= 2463 occasions) based on this coding. For example, if crackers seemed to be a substitute for bread and were eaten with cheese, crisps, fruit, yoghurts etc, then all items would be ‘snack’ items but seemed to be more in line with a lunch meal. Similarly meal items such as crumpets, pancakes, waffles and teacakes may be eaten at a breakfast meal, but equally may be eaten as snacks during the day. Such issues were discussed at a departmental meeting among colleagues with expertise in diet and nutrition, and a final, refined coding frame was finalised (**Table 3.8**). Changes were made to the original coding frame such as raw vegetables becoming classified as a snack, and a new category termed ‘sweet breads’ was created to include teacakes, brioche, fruit loaf etc. Using this coding frame I compared my coding with that of the parents’ (for cases where parents had coded occasions as meals or snacks) and there was high agreement (Kappa= 0.82). However, given the difficulties that arose from attempting to code occasions as meals and snacks using our coding frame, for example in young children a number of ‘snack’ items may constitute a lunch, not to mention the parents’ ambiguity about what constitutes a meal and what constitutes a snack, I decided to define an eating occasion as any occasion in which food was consumed, rather than code meals and snacks separately.

As described in **Chapter 1**, there is no clear consensus in the literature as to how best to define meals and snacks (Leech et al. 2015). It is far easier to distinguish between occasions that contain food items and those that only contain drink items. It was therefore more straightforward to code occasions as simply eating or drinking occasions, and not to further divide eating occasions into meals and snacks. It also meant I was able to compare subsequently derived parameters of eating occasions (size and frequency) with the same parameters for drinking occasions.

Drinks consumed at the same time as food were included in my definition of an ‘eating occasion’, and interestingly when exploring the parental coding of meals and snacks, often when drinks were consumed with food items parents deemed the occasion a ‘meal’ or a ‘snack’. This provides some justification for my method of coding. A number of studies define an ‘eating occasion’ as a consumption occasion i.e. any occasion in which energy is consumed (Drummond et al. 1998; Popkin & Duffey 2010) and based on my definition I was able to additionally explore this by combining eating and drinking occasions together. I did not wish to define occasions based on the amount of energy consumed, despite the suggestion by Gibney and Wolever (1997) that an eating occasion should contain a minimum energy content of 210 kJ (Gibney & Wolever 1997). I was interested in energy intake as an outcome throughout this thesis, and I was also interested in behavioural differences between children that explain variation in energy intake – i.e. *how* food and drinks are consumed as well as *how much* is consumed. Therefore I opted for a simpler coding system based on whether the items consumed were foods or drinks.

A random sample of occasions (5%; 2645 occasions) was second coded as eating and drinking occasions by an experienced dietician at University College London, to assess inter-rater reliability. Complete agreement (Kappa= 1.00) was reached and this assured me that the coding of eating and drinking occasions was reliable.

Table 3.6. Parental classification of items within consumption occasions[a]

Classification	Frequency (*n* (%))	Cumulative percent
Meals	21594 (40.8)	40.8
Snacks	19404 (36.7)	77.5
Drinks	903 (1.7)	79.2
Not specified	7456 (14.1)	93.3
Meals and not specified	1403 (2.7)	95.9
Snacks and not specified	508 (1.0)	96.9
Drinks and not specified	16 (0.01)	96.9
Meals and snacks	1118 (2.1)	99.0
Meals and drinks	253 (0.5)	99.5
Snacks and drinks	135 (0.3)	99.8
Meals, snacks and drinks	15 (0.01)	99.8
Meals, snacks and not specified	90 (0.2)	100.0
Meals, drinks and not specified	8 (0.001)	100.0
Snacks, drinks and not specified	2 (0.001)	100.0
Meals, snacks, drinks and not specified	3 (0.001)	100.0

Abbreviations: %, percentage

[a] Parents were asked to classify items within a consumption occasion as a snack or meal. Some parents also created another category of ‘drinks’. There were also items not classified by parents (‘unspecified). All combinations of parent coding for items within each consumption occasion were computed, for example ‘meals’ refers to consumption occasions in which all food items within an occasion were classified as a meal by parents. ‘Meals and not specified’ were occasions in which some food items were classified as meal items but others were not classified.

Table 3.7. Initial classification of food and drinks into meal and snack categories (adapted from Macdiarmid et al (2009)

Meal foods	**Snack foods**
Bread, excluding wholemeal	Puddings
Wholemeal bread	Cream
Wholegrain & high-fibre cereals	Cheese
Other breakfast cereals	Yogurts, fromage frais, yogurt drinks
Eggs and egg dishes	Ice cream (dairy and non-dairy)
Meats and meat dishes, exc. processed meat	Confectionery
Processed meat (sausages, burgers, coated chicken)	Crisps and savoury snacks
Fish and fish dishes, exc. oily fish	Nuts and seeds
Oily fish & dishes	Sugar and preserves
Vegetables, exc. potatoes and baked beans	Fruit (fresh, canned, cooked, dried), exc. fruit juice
Chips, fried/roasted potatoes	Fats (margarine/butter) and oils
Other potatoes (boiled, mashed, baked, grilled)	Soups and sauces
Baked beans	

Table 3.8. Final classification of food and drinks into meal and snack categories (adapted from Macdiarmid et al (2009)

Meal foods	Snack foods
Bread, excluding wholemeal	Cakes and pastries
Wholemeal/white/granary	Cheese scones
Chapatti	Cheese pastries
Pitta bread	Croissants
Tortilla wraps	Sweet bread
Crumpets	Hot cross buns
English muffins	Teacakes
French toast	Brioche
Wholegrain & high-fibre cereals	Scotch pancakes
Other breakfast cereals	Fruit bread
Eggs and egg dishes	Milk bread
Meats and meat dishes, excluding processed meat	Malt/fruit loaf
Processed meat	Iced buns
Sausages	Puddings
Sausage rolls	Cream
Pork pies	Cheese
Burgers	Yogurts, fromage frais, yogurt drinks
Coated chicken	Ice cream (dairy and non-dairy)
Scotch eggs	Confectionery
Fish and fish dishes, excluding oily fish	Crisps and savoury snacks
Oily fish & dishes	Crackers
Cooked vegetables	Breadsticks
Chips, fried/roasted potatoes	Rusks
Other potatoes (boiled, mashed, baked, grilled)	Rice cakes
Baked beans	Nuts and seeds

Soups	Sugar and preserves
Non-meat alternatives	Fruit (fresh, canned, cooked, dried), excluding fruit juice
Falafel	Fats (margarine/butter) and oils
Quorn	Sauces
Tofu	Condiments
	Custard
	Dips e.g. hummus
	Raw vegetables

3.2.2.4.4.2 Consumption patterns

Once each occasion had been coded as an eating or drinking occasion the data were restructured to combine all occasions that took place during the same day for each twin, and restructured further to combine each child's three days of diary entries. Meal sizes and frequencies were derived for eating occasions (occasions in which food was consumed, and drinks if consumed alongside food), drinking occasions (occasions in which only drinks were consumed, excluding water), and total consumption occasions (eating and drinking occasions per day combined). These were derived for each child, averaged over three days. The term 'meal size' is used throughout this thesis to refer to the amount of kilojoules consumed during each eating/drinking/consumption occasion, and the term 'meal frequency' is used to refer to the number of eating/drinking/consumption occasions per day. A number of meal size and frequency variables were computed.

MEAL FREQUENCY

Meal frequency (consumption occasions): average total number of consumption occasions (eating and drinking occasions combined, excluding water) per day.

Meal frequency (eating occasions): average total number of times per day any food (and drinks if consumed with food) was consumed.

Meal frequency (drinking occasions): average total number of times per day any drinks (including formula and breast milk, excluding water) were consumed without food.

I decided to exclude from drinking frequency any occasions in which only water was consumed as water occasions would provide no energy, and therefore would not contribute to meal size for drinking occasions. It would however increase the number of drinking occasions, thereby skewing the data.

MEAL SIZE

Meal size (consumption occasion): Average amount of kJ consumed during each consumption occasion (eating and drinking occasions combined). This was calculated as the average daily energy intake divided by the number of eating and drinking occasions (excluding water) per day.

Meal size (eating occasion): Average amount of kJ consumed during each eating occasion. This was calculated as the average daily energy intake from eating occasions divided by the number of eating occasions per day.

Meal size (drinking occasion): Average amount of kJ consumed during each drinking occasion (including formula and breast milk, excluding water). This was calculated as the average daily energy intake from drinking occasions divided by the number of drinking occasions per day.

3.2.2.4.4.3 Meal composition

The composition of eating occasions was explored by calculating the average weight (g) of each eating occasion, the average energy density (kJ/g) of each eating occasion, and the percentage of meal energy (%mE) from protein, carbohydrate and fat, for each child.

Meal weight (g) was defined as the average amount of grams consumed per eating occasion and was calculated by dividing the total number of grams consumed in eating occasions per day by the number of eating occasions per day.

Meal energy density (kJ/g) was calculated by dividing the energy intake (kJ) of each eating occasion (including drinks consumed at the same time as food) by the weight (g) of each eating occasion.

Meal energy density excluding drinks (kJ/g) was calculated by dividing the energy intake (kJ) of each eating occasion (with drinks consumed at the same time excluded) by the weight (g) of each eating occasion (with drinks consumed at the same time excluded). The reason for this was because my definition of an eating occasion includes drinks consumed at the same time as the food; however, the implication for energy density of including drinks with eating occasions (when not all eating occasions include them) is that an eating occasion with a drink will automatically be of lower energy density, even if the same food was eaten. This is often because the majority of drinks are water and thus add weight but comparatively little energy to the occasion (Rolls et al. 1999).

Percentage meal energy (%mE) from fat was calculated by first multiplying the number of grams of fat per eating occasion by the amount of energy found in one gram of fat (37.7 kJ) (Maclean et al. 2003) to give the total energy from fat per eating occasion. This was then divided by the total energy in each eating occasion and multiplied by 100.

Percentage meal energy (%mE) from protein was calculated by first multiplying the number of grams of protein per eating occasion by the amount of energy found in one gram of protein (13.4 kJ) (Maclean et al. 2003) to give the total energy from protein per eating occasion. This was then divided by the total energy in each eating occasion and multiplied by 100.

Percentage meal energy (%mE) from carbohydrate was calculated by first multiplying the number of grams of carbohydrate per eating occasion by the amount of energy found in one gram of carbohydrate (16.7 kJ) (Maclean et al. 2003) to give the total energy from carbohydrate per eating occasion. This was then divided by the total energy in each eating occasion and multiplied by 100.

3.2.2.4.4.4 Energy and nutrient intakes

Daily energy intake was derived for each child, averaged over three days. **Daily energy intake from eating occasions** and **daily energy intake from drinking occasion**s (including formula milk and breast milk) were also calculated.

Within the dataset all food and drink items had codes assigned to them, for example items with codes 05.01 or 05.02 or 05.03 or 05.08 were cow's milk. This meant that daily intakes of specific food and drink items could be calculated. Therefore **daily energy intake from food**, **daily energy intake from formula milk**, **daily energy intake from cow's milk** and **daily energy intake from total milks** were computed. The **percentage of energy intake (%E) from food**, **%E from formula milk**, **%E from cow's milk** and **%E from total milks** were all calculated by dividing each by daily energy intake and multiplying by 100. In addition, formula milk specific parameters were derived, in order to explore formula milk consumption in further detail: **formula milk frequency** (the average total number of times per day formula milk was consumed); and **energy intake per formula occasion** (the average amount of kJ consumed per formula milk occasion).

Daily intakes of macronutrients and the components (**total fat**, **saturated fat**, **protein**, **carbohydrate**, **starch**, **fibre** and **sugars**[d]) were calculated as total grams per day (g/d). The percentage of daily energy intake (%E) from total fat, saturated fat, protein and carbohydrate were computed by first multiplying the number of grams of each macronutrient by the amount of energy found in one gram of each (approximately 38, 38, 13, 4 and 17 kJ respectively) (Maclean et al. 2003). This gave the total energy in each macronutrient per day which was then divided by daily energy intake and multiplied by 100. %E from sugar was calculated by dividing the number of grams of sugar by the total number of grams consumed per day.

Daily intakes of selected micronutrients (**sodium**, **vitamin C**, **thiamin**, **riboflavin**, **niacin**, **folate**, **vitamin B-12**, **calcium**, **vitamin D**, **vitamin A**, and **iron**) were calculated as milligrams (mg) or micrograms (µg) per day, both including and excluding supplement intake.

Daily energy density was calculated as daily energy intake (kJ) divided by the total grams consumed in food and drinks per day.

3.2.2.4.5 Estimating misreporting of dietary intake

Self-report methods of dietary assessment rely on individuals accurately recording their dietary intake. Misreporting, and particularly under-reporting is well documented in adults (Livingstone et al. 1990) and in children (Livingstone et al. 1992; Bandini et al. 1997). Objective measures of energy expenditure (EE) such as the Doubly Labelled Water (DLW) method, outlined in **Chapter 1**, are the most reliable means of validating reported energy intakes in dietary assessment. A direct comparison is made between energy intake and energy expenditure, with the assumption that if body weight remains stable during measurement, energy intake will equal energy expenditure. If the two are unequal then energy intake has been misreported.

However, as such methods are costly and require extensive resources, their use in large-scale studies is not feasible. Therefore an alternative

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[d] Data on sugar components (non-milk extrinsic sugars and intrinsic milk sugars) were not available as it was not requested at the time HNR coded the dietary data

method was used to assess under-reporting in the large Gemini sample, which relied on predictions of energy expenditure. The individualised method (Rennie et al. 2007) assumes that EE is equal to the child's estimated energy requirements (EER) and therefore each child's reported energy intake (EI) is compared to their EER as an estimate of energy expenditure (EE). EI is subtracted from EER (EER-EI) to determine whether the energy intake reported is 'plausible'. As exact agreement between EI and EER is unlikely using three day diaries due to day to day variation in both EI and EE (and reporting error), the individualised method allows for this inherent variation. An upper and lower plausible agreement of EI and EER can be calculated by adding and subtracting a coefficient of variation (CV_t).

EER is calculated from **EE** and the energy required for growth (**E_g**):

EER = EE + E_g

First **EE** was calculated using age(1-18 years) and sex-specific standard equations developed using collated DLW energy expenditure data in children (Torun 2007).

Boys: EE (kJ / day) = 1298 + 63.3kg – 0.263kg^2 (boys)

Girls: EE (kJ / day) = 1102 + 65.3kg – 0.454kg^2 (girls)

Body weight is included in the equation but as weight was not measured at the time of diary completion (approximately 21 months) it was imputed for all children. Weights at 21 months were imputed using interpolation[e] in a multi-level model that used all available weight measurements between zero and five years of age to fit a growth curve for each child.

The next step was to calculate **E_g** using the equation: mean weight gain (g/day) * 8.6 (KJ/g). The value for mean weight gain can be obtained from DLW energy expenditure data (Torun 2007) and is also age and sex specific. Values are given for children one to 1.9 years (6.6 g/day for boys and girls) or two to 2.9 years (5.0 g/day for boys and 6.0 g/day for girls). Given the age of our sample (mean= 20.7 months, SD= 1.2, range= 17.1 –

[e] Interpolation was conducted by Dr David Boniface

33.7) the decision was made to use the weight gain/day for one to 1.9 years in the equation.

The coefficient of variation (CV_t) of EI/EER was calculated using methods derived from DLW methods (Black & Cole 2000) using the following equation:

$$CV_t = \sqrt{CV_{EE}^2 + \frac{CV_{EI}^2}{d}}$$

d= number of diary days (d=3)

CV_{EE}= CV for measurement of EE (19.1%, the average from DLW studies on which EER equations are based)

CV_{EI}= CV for measurement of EI (5.5% at age 21 months calculated from Gemini data as the average CV_{EI} of all children in the sample; obtained by dividing the mean EI for each child by the standard deviation of EI for each child)

Based on the equation, CV_t = 19.37%. This is the level of variation around EER considered plausible energy intake reports. Energy intakes between 80.63% and 119.37% (100% +/- 19.37%) of EER values were therefore considered within the range of normal measurement error associated with estimating EI and EER. Individuals with reported EI below 80.63% of their EER were defined as under-reported and individuals with EI above 119.37% of their EER were defined as over-reported. **Table 3.9** shows the number of children classified as under (12.4%), over (11.9%) and plausibly (68.1%) reported within the diary sample at 21 months.

Table 3.9. Frequency (%) of misreporting categories (EI/EER) for the Gemini sample

	Under-reported	**Plausibly reported**	**Over-reported**
Full sample[a]	288 (12.3)	1590 (68.1)	278 (11.9)
Boys	179 (15.5)	754 (65.2)	127 (11.0)
Girls	109 (9.2)	836 (70.9)	151 (12.8)

Abbreviations: %, percentage; EI, energy intake, EER, estimated energy requirements

[a] The full sample (*n*= 2156) does not equate to the full sample of children with dietary data (*n*= 2336) as individual children were excluded from the imputation model if they did not have birth weight and at least two weight measurements from age at diary completion to five years of age.

3.2.2.5 Dietary intake (seven years of age)

During April and December 2014, when the twins were approximately seven years old, families who were still engaged with the Gemini study were sent a letter (**Appendix 3.14)** inviting them to complete a second diet diary, which was sent at the same time **(Appendix 3.15)**. Families were considered actively engaged (*n*= 1845 families; 77% of baseline sample) if they had not withdrawn or been lost to follow up and had completed questionnaires at baseline and when the twins were approximately 16 months old. The diaries were sent in a staggered form in order to coincide approximately with the twins' birthdays. The diet diary was slightly adapted from that used at 21 months, for example references to formula milk were removed, but it remained parent-report as children younger than eight years old are generally not considered able to recall foods accurately, estimate portion size or conceptualise frequency of consumption (Livingstone & Robson 2000).

3.2.2.5.1 Portion guide

1845 families were also sent a portion guide (**Appendix 3.16**) which was adapted from that of the portion guide sent when the twins were 21 months, with photographs of portion sizes taken from the Young Person's Food Atlas for primary school children (four to 11 years) (Foster et al. 2010b) rather than the preschool food atlas (18 months to four years) (Foster et al. 2010a). The

Primary School Food Atlas was developed using data from the National Diet and Nutrition Survey for children aged four to 18 years (Lowe et al. 2000). To remain in line with the process used at 21 months, I used the same 18 food items, and this time the mid-point five photographs were taken from the seven images of food weights served in the food atlas. This was because the Gemini twins were seven years old but the Primary School Food Atlas is for children four to 11 years old. Parents were asked to depict the amount consumed by their twins from one of the five photographs (A, B, C, D, E).

By age seven the majority of children would be attending school so parents were asked to complete the diary on two week days and one weekend day during the next school holiday or half term. It was acknowledged that dietary intake may differ during holidays to term-time but I wanted to remain consistent with the first diary, in which parents were largely aware what their child was consuming as they were serving it. I felt there would be more room for error and more missing data if school meals, with the parent absent, were reported.

3.2.2.5.2 Diet diary

309 families (16.7% of those invited) completed the seven year food diaries for their twins (*n*= 618 children). 281 families completed three days, 16 families completed two days, and 10 families completed one day of entries. This was considered a reasonable response rate given that the cohort were now seven years on from baseline, and the time taken to complete the diary. In order to contrast dietary data from 21 months with that at seven years, I was interested in which of the families with three days of dietary data at seven years, also completed a three day diary at 21 months. 222 families (79% of those completing three-day diaries at seven years) had dietary data at both time points. Of these, 145 families had complete data on the CEBQ at 16 months and seven years, and due to financial constraints, a random sample of these were selected for coding (*n*= 100 families; 200 children). The random sample was selected using the 'Rand()' function in Excel which assigns random numbers to each family (between 0-1). Using the sort function numbers were listed from lowest to highest and the top 100 were selected as the 100 diaries to be coded.

Table 3.10 shows the characteristics of the twins with three day diet diary data at seven years of age (n=200) compared with the baseline sample (*n*= 4804). The baseline sample used for comparison consisted of all children without dietary data at seven years of age. Children had a mean age of 84.76 months (SD= 1.38) at the time of diet diary completion (7.01 years). Compared to the baseline sample, the diet diary sample had more highly educated mothers, the twins had a lower birth weight standard deviation score, and were born slightly later. There was also a higher proportion of children in the diet diary sample that had been breast fed during the first three months from birth.

Table 3.10. Diet diary sample characteristics (seven years of age)

	Diet diary sample (*n*= 100 families; *n*= 200 twins)	**Baseline sample** (*n*= 2402 families; *n*= 4804 twins)	***p*-value[a]**
Sex, N (%)			0.34
Boys	106 (53.0)	2386 (49.7)	
Girls	94 (47.0)	2418 (50.3)	
Ethnicity, N (%)			0.11
White	192 (96.0)	4178 (87.0)	
Non-white	8 (4.0)	626 (13.0)	
Maternal education[b], N (%)			<0.001
Low/intermediate	68 (34.0)	2792 (58.1)	
High	132 (66.0)	2012 (41.9)	
Age at diary completion (m), mean (SD)	84.76 (1.38)	-	-
Weight at birth (kg), mean (SD)	2.49 (0.51)	2.46 (0.54)	0.52
Weight SDS at birth (kg), mean (SD)	-0.71 (0.92)	-0.56 (0.95)	0.02
Gestational age (wk), mean (SD)	36.63 (2.22)	36.20 (2.48)	0.01
Feeding method (0-3 months) (n(%)			<0.001
Breast-fed infants	180 (90.0)	3486 (73.1)	<0.001
Bottle-fed infants	16 (8.0)	1090 (22.8)	

Abbreviations: %, percentage; SD, Standard deviation; m, months; kg, kilograms, wk, weeks

[a] P-value for difference between the seven year diet diary sample and full Gemini sample on listed characteristics

[b] Maternal educational attainment was dichotomized into low/intermediate (no university level education) and high (university education).

[C] The proportion of infants breast fed in the first three months from birth was obtained with the question "which feeding method did you use in the first 3 months?" with response options ranging from 1=entirely breast feeding to 6=entirely bottle feeding. Categories 1-5 were classified as 'breast fed' and category 6 as 'bottle-fed'.

3.2.2.5.3 Coding of dietary data

The seven year diet diary data was coded in the same way as the 21 month diary in order to be consistent. Given the high inter-rater agreement for the coding of occasions as eating or drinking occasions found previously, and the reduced number of occasions at seven years (*n*= 15870 entries as opposed to *n*= 52,908 at 21 months), I did not deem it necessary to repeat the inter-rater check a second time.

In line with the procedure for coding at 21 months of age, the dietary coding was carried out using DINO (Fitt et al. 2014) at the Medical Research Council Human Nutrition Research (HNR) in Cambridge. Diaries were quality checked for completeness. If there was a large amount of missing data within a diary, for example an incomplete day (*n*= 4 diaries), another three-day diary was selected from the random sample and used as an alternative. If a portion size was not reported by parents, coders at HNR used existing DINO portions as the default option, which were standardised portion sizes for children aged seven years (using the same method as previously). All variables computed at 21 months of age were also computed at seven years of age.

3.2.3 Statistical analyses

Throughout this thesis a range of analyses have been conducted, utilising both qualitative and quantitative methods. For all quantitative analyses the alpha value was set at $p < 0.01$ because although $p < 0.05$ is often the conventional value used to determine statistical significance, the Gemini sample is large and therefore offers more power to detect statistically significant associations. For consistency throughout this thesis, the *p*-value for analyses involving the sub-sample of 200 children was also set at $p < 0.01$ despite the much smaller sample size.

3.2.3.1 Non-response analyses

Non-response analyses were conducted on the samples within each study in this thesis. This was to establish how the study samples differed from those who did not respond to the assessment measures. Each analyses included five variables (sex, ethnicity, maternal education, birth weight SDS and gestational age). Pearson's chi-square tests were used to assess differences between responders and non-responders in terms of sex, ethnicity and maternal education. Independent samples t-tests were used to assess mean differences in birth weight SDS and gestational age.

3.2.3.2 Quantitative analyses

A number of different quantitative methods were used to analyses data throughout this thesis. Dietary intakes among the Gemini sample were compared with i) those of the National Diet and Nutrition Survey (NDNS) sample using linear regression models, and ii) Dietary Reference Values (DRVs) using one-sample t-tests. Complex Samples General Linear Models (CSGLMs) were used throughout this thesis to explore associations between dietary variables and i) appetite and ii) adiposity. These take into account the clustering of twins within families and allow the full sample to be utilised. Mediation analyses were conducted to explore inter-relationships between appetite, eating patterns and adiposity, and multi-level models explored associations between dietary variables and weight gain. The stability and change in appetite and dietary intake was assessed using partial correlations and General Linear Mixed Models (GLMMs) respectively. All analyses are described in more detail within each chapter.

3.2.3.3 Qualitative analyses

Content Analysis was used to interpret qualitative data (Cole 1988). This is a method of qualitative analysis in which text is systematically coded, and interpretations are made to extract the content or contextual meaning. The process of content analysis involves reading the interview transcript a number of times in order to become familiar with the data. Any interesting observations or comments of significance can be highlighted at this stage. The process used within this thesis is described further in **Chapter 5**.
The data analysis software package NVivo (NVivo Qualitative Data Analysis Software. Version 10 2012) was used to code data.

3.2.3.4 Power

Post-hoc power calculations were carried out using G-Power (version 3.0.10; Softpedia) to determine if the sample of 200 children at seven years of age provided sufficient power to detect a medium effect size (for both stability and change in dietary intake, eating patterns and appetite), at an alpha level of 0.05 given the small sample size. Power calculations were based on correlations. The sample of 200 children provided 99% power to detect a medium effect (*r*= 0.3) and was therefore sufficient to explore tracking over time.

3.3 Discussion

Gemini is a large population-based cohort of twins making it possible for me to explore interrelationships between what children eat (diet quality), how children eat (eating patterns), appetitive traits and adiposity. The collection of multiple weight measurements over time provides the means to explore weight gain with some confidence, and the large sample means that small associations can be detected.

The cohort itself differed in some ways from the target population initially contacted by the ONS. For example the proportion of families across England and Wales was not equal, with most participating families in the South East of England, and the fewest number of families in London. Nevertheless, the distribution largely mirrored the population density. There were also slightly fewer mothers in the older and younger age groups but overall a reasonable proportion of mothers across all age categories.

The twins participating in Gemini were representative of national twin statistics on sex, gestational age, zygosity and birth weight. However, twins are often born earlier than singletons and as a result there is a greater possibility of postnatal issues such as feeding difficulties. As a result, this thesis adjusts for gestational age in all analyses.

In-line with many cohort studies, there is an over-representation of parents of white ethnicity in Gemini compared to the larger population. Parents also tended to be older at the twins' birth, had lower BMIs, higher educational attainment, and higher socio-economic status than the national population. However, there were a considerable number of families in all categories of socio-demographic characteristics suggesting the cohort includes a range of families from different backgrounds.

In summary, the Gemini cohort provides a large and reasonably representative sample to explore interrelationships between appetite, eating patterns and adiposity in early life.

CHAPTER 4. DIETARY INTAKES OF YOUNG CHILDREN IN THE UK[f][g]

4.1 Background

In order to understand *what* children are eating, as well as *how* they are eating, and the potential impact of this on health, good quality dietary data is needed. Beyond 18 months of age, when weaning is close to, or at completion, little is known about the dietary intakes and eating behaviours of young children in the UK. This is despite the fact that dietary habits in early life may have long term consequences for weight and subsequent health.

The nutritional composition (energy intake, macro- and micro-nutrients) of young children's diets, as well as data on specific eating patterns (meal sizes and meal frequencies) need to be assessed if we are to identify dietary factors that might contribute to weight gain and ill-health in early life.

There have only been a few detailed large-scale national studies of dietary intake in young children in the UK. A large study was conducted in England over 20 years ago of children aged 18 months; the Avon Longitudinal Study of Parents and Children (ALSPAC). The study used three day diet diaries to collected detailed dietary information from 1026 children (Cowin & Emmett 2007). However, this study was conducted in 1994, and since that time there have been significant increases in levels of childhood obesity (Stamatakis et al. 2010), as well as changes to the modern food environment. It is therefore important to re-assess young children's intakes in more recent times. This would allow comparisons with current dietary guidelines – some of which have been updated in recent years – as a means of assessing whether young children in the UK are meeting dietary guidelines. As well as this, more current dietary data would allow comparisons with previous time points, such as data from ALSPAC in 1994.

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[f] Data from this chapter has been published as a paper in the British Journal of Nutrition (Syrad, Llewellyn, van Jaarsveld, et al. 2016)
[g] The peer-review process resulted in changes to this chapter, such as the drawing of comparisons with ALSPAC, acknowledgement of additional methodological differences between Gemini and NDNS data collection, the use of weighted NDNS data rather than unweighted data, and adjustment for additional confounders (ethnicity and SES).

The Diet and Nutrition Survey of Infants and Young Children (DNSIYC) was a one-off survey which collected data on food and nutrient intakes from 2683 children aged four to 18 months old in the UK (Lennox et al. 2013). The study, conducted in 2011, provided nationally representative information on dietary intake. However, the age range included both exclusively milk-fed infants and young children consuming a more established solid food diet. There is a need for dietary data from a large sample of young children beyond 18 months who are close to or have completed weaning in order to identify whether children are meeting dietary recommendations when consuming little or no breast or formula milk (Stephen et al. 2013b). To date there is limited information within this age group. The National Diet and Nutrition Survey (NDNS) is a routine survey conducted annually to collect dietary data from individuals aged 18 months and older in Britain. Four day unweighed diaries are used as the method of data collection. However, currently the sample size for young children is small; with dietary data available for only 386 children aged 18-36 months from 2008 to 2012 (Bates et al. 2014). In order to obtain a more accurate picture of intakes across the UK population larger-scale surveys are required. Nevertheless, the NDNS sample would provide a useful indication of the diets of a sample of singletons in the UK, with which to make comparisons if a larger scale survey was available.

The Gemini twin study is a large population based cohort and provides an opportunity to examine *what* and *how* young children are eating. The twin nature of the study however may mean that findings are not generalizable to the wider population. Therefore there is a need to examine the representativeness of findings in comparison to data from a sample of young singletons in the UK. This would help to demonstrate whether dietary data from the Gemini sample is a valuable resource for studies of diet and health outcomes; the prospective design enables potential causal associations to be investigated.

4.2 Study aim

The present study uses comprehensive dietary data from 2336 children aged 21 months, collected in 2008/09 using three-day unweighed diet diaries to provide information on young children's dietary intakes and eating patterns.

The main objectives of the study were to: i) Describe the daily energy and nutrient intakes from food and drinks for children aged 21 months in the UK, ii) describe the average size and frequency of eating and drinking occasions for children aged 21 months in the UK, iii) compare the energy and nutrient intakes, and the meal size and frequency of eating and drinking occasions of Gemini twins to those of 386 children aged 18-36 months in the nationally representative NDNS rolling programme (2008-12); and iv) compare the energy and nutrient intakes of the Gemini twins at 21 months to UK public health nutrition recommendations for energy and nutrient intakes at two years of age in order to assess whether children are meeting dietary guidelines.

4.3 Methods

4.3.1 Study populations

Dietary data were obtained from 2336 children in the Gemini sample when they were aged approximately 21 months. Gemini participant recruitment and the Gemini sample used in the current study have both been described in **Chapter 3**.

For comparison with the Gemini sample, dietary data from 386 children aged 18-36 months from the NDNS rolling programme were included (Bates et al. 2014). The NDNS rolling programme is conducted by three organisations: the National Centre for Social Research (NatCen) in London, the Medical Research Centre Human Nutrition Research group at the University of Cambridge, and the Department of Epidemiology and Public Health at University College London. The sample across the first four years (2008-2012) was drawn from the Postcode Address File (PAF), a list of all addresses in the UK. Addresses were clustered into Primary Sampling Units (PSUs) which were randomly selected small geographical areas across the UK. A list of addresses was then randomly selected from each PSU and a letter was posted to them describing the purpose of the survey. Following this, a face-to-face visit by an interviewer took place to recruit participants. Within each selected household the interviewer randomly selected up to one adult and one child to take part in the survey and complete a diet diary. 4156 diet diaries were completed (for participants ranging from 18 months to 94 years); 386 (9.3%) respondents were parents of children aged 18 to 36 months.

4.3.2 Measures

4.3.2.1 Dietary intake

Dietary data for the Gemini sample were collected using three day unweighed diet diaries, completed over two weekdays and one weekend day (described in **Chapter 3**). Data were collected from November 2008 to August 2009. The energy and nutrients consumed from all food, drinks and vitamin supplements were calculated using DINO (Fitt et al. 2010). This is described in more detail in **Chapter 3**. Children with three days of complete diary entries (*n*= 2336) were included in the current analyses.

Dietary data from the NDNS sample used for comparison in the current study (*n*= 386) were collected using four day unweighed diet diaries, completed by parents over four consecutive days. Dietary data were collected between February 2008 and April 2012. Trained interviewers visited respondents in person or conducted interviews over the telephone to provide parents with the diary and explain the method. Parents were shown the different sections including the instruction page, how to describe details of food and drink and portion sizes, and an example day. On the second or third day of recording, the interviewers visited or telephoned participants again to check the food diaries. The aim of this being to obtain missing details for reported intakes, and thereafter improving recording for the remaining days. Interviewers collected the diary at the end of the recording period; no later than three days after the fourth and final day of recording, and checked the diaries.

Parents were asked to keep the food diary on behalf of participants aged 11 years and younger, with children contributing information where possible, and with help from other carers. Portion sizes were estimated by respondents using household measures, for example two thick slices of bread, four tablespoons of peas, or using weights from labels, such as 300g tin of tomato soup, 330ml can of Coca-Cola. The food diaries also contained images of life-size cutlery and crockery to assist with reporting. In year four of the rolling programme, parents of children aged 18 months to four years were provided with images of thirty-one different foods from the Young Person’s Preschool Food Atlas (Foster et al. 2010a). There were seven images for ‘as served’ portions and seven images for ‘leftover’ portions. Most photographs could be used to estimate amounts for other foods in addition to the actual foods shown, for example, rice could also be used for couscous. Parents were asked to select the appropriate portion sizes consumed by their child using the atlas. Energy and nutrient intakes were calculated using DINO, as they were in Gemini. Details on the methodology can be found in **Chapter 3**. The methods used for the NDNS and Gemini were therefore similar, allowing for reasonable comparison across the two samples.

4.3.3 Statistical analyses

4.3.3.1 Descriptive statistics

4.3.3.1.1. Energy and nutrient intakes

Within the Gemini sample, each child's daily energy, macronutrient (total fat, saturated fat, protein, carbohydrate, starch, fibre and sugars[h]) and micronutrient (sodium, vitamin C, thiamine, riboflavin, niacin, folate, vitamin B-12, calcium, vitamin D, vitamin A, and iron) intakes were computed, as an average over the three days of entries. This process has been described in **Chapter 3**. Energy and macronutrients were summarised as total grams per day (g/d), and percentage of daily energy intake (%E); micronutrients were summarised as milligrams (mg) or micrograms (µg) per day. These were calculated with and without the inclusion of supplements. Descriptive analyses including the mean, standard deviation (SD), minimum, maximum and 25th and 75th percentile scores were computed for all dietary intake variables.

Dietary data for children aged 18-36 months across the first four years (2008/9–2011/12) of the NDNS rolling programme were obtained from the UK Data Archives (http://discover.ukdataservice.ac.uk/catalogue?sn=6533). All energy and nutrient intakes derived in the Gemini dataset were also available in the NDNS dataset. Intakes had been averaged over the four days of entries (Bates et al. 2014). In order to adjust for any potential bias in the results such as non-response bias, or socio-demographic differences between the NDNS sample and the UK population, the data were weighted[i]. The weighting adjusts for known socio-demographic differences between the survey sample and that of the total population of the UK, in terms of age, sex and government office region. Weighted mean scores and intakes as a percentage of Dietary Reference Values were computed.

4.3.3.1.2 Meal size and frequency

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[h] Data on sugar components (non-milk extrinsic sugars and intrinsic milk sugars) were not available as it was not requested at the time of diary coding

[i] The weighting of data was carried out by Dr Laura Johnson.

The average meal size and meal frequency among the sample was calculated for eating occasions, drinking occasions and consumption occasions. The method is described further in **Chapter 3**, but in brief 'meal size' refers to the amount of energy consumed during each eating/drinking/consumption occasion, and the term 'meal frequency' refers to the number of eating/drinking/consumption occasions per day.

4.3.3.1.3. Food and drink intakes

The method used to compute food and drink intake variables is described in **Chapter 3**, but in brief, daily energy intake, daily energy intake from eating occasions only and daily energy intake from drinking occasions only (including formula milk and breast milk) were calculated. In addition, average daily energy intake from food per day (minus drinks that were consumed with food), daily energy intake from formula milk, daily energy intake from cow's milk and daily energy intake from total milks were computed. The percentage of energy intake (%E) from food, %E from formula milk, %E from cow's milk and %E from total milks were also all calculated.

4.3.3.2 Comparisons between Gemini and the National Diet and Nutrition Survey (NDNS)

Daily intakes of energy, macronutrients and micronutrients within Gemini were compared to the weighted mean scores and intakes in the NDNS using linear regression models. These tested for differences between the samples, with energy and nutrient variables as the dependent variables, and the sample (Gemini and NDNS) as a predictor. All models included age, sex, ethnicity (categorised as white and non-white) and SES (categorised using the NS-SEC; higher, intermediate and lower SES) as covariates. P-values were set at <0.01 for all analyses.

4.3.3.3 Comparisons with Dietary Reference Values

UK Dietary Reference Values (DRVs) were used to assess the adequacy of energy and nutrient intakes. The DRVs that exist within the UK are age and sex specific. Multiple criteria were used in the current study to assess adequacy of intakes. Average daily energy intake was calculated as a percentage of the 2011 Scientific Advisory Committee on Nutrition (SACN) Estimated Average Requirement (EAR) for children two years of age (Scientific Advisory Committee on Nutrition 2011). Intakes of protein and micronutrients were calculated as a percentage of the Department of

Health Reference Nutrient Intake (RNI) for children aged one to three years of age (Department of Health 1991). Carbohydrate and fibre intakes were compared with the SACN (2015) recommendations for children aged two to five years (Scientific Advisory Committee on Nutrition 2015a). Comparisons could not be made for fat intakes as DRVs are unavailable for children under five years of age. Sodium intake was calculated as a percentage of the updated RNI for children two years of age by SACN (2003) (Scientific Advisory Committee on Nutrition 2003). The proportion of children with inadequate intakes of micronutrients was determined using the RNI and Lower Reference Nutrient Intake (LRNI) (Department of Health 1991). The LRNI is the level at which intake is inadequate for 97.5% of the population. An upper safe limit for vitamin A retinol activity equivalent (RAE) of 800μg has been identified by the European Food Safety Authority (Scientific Committee on Food 2006) and the percentage of children exceeding this limit was calculated. No upper limits were available for other micronutrients. In order to compare daily intakes of energy, protein and micronutrients with DRVs one sample t-tests were used. The intakes of Vitamin D and iron, with and without supplementation, were compared using paired samples t-tests.

4.4 Results

4.4.1 Sample Characteristics

Table 4.1 shows the characteristics of the children in the Gemini sample (*n*= 2336) and those in the NDNS sample (*n*= 386). Children in Gemini had a mean age of 20.6 months (SD= 1.1) at the time of diet diary completion. There were an equal number of boys (49.5%) and girls in Gemini and many more families of white (95.1%) than non-white ethnicity. Parents were more likely to be of higher SES (46%) than intermediate (16.1%) or lower (37.9%) in Gemini and the majority (62.8%) of children were breast-fed during the first three months from birth. Children in the NDNS sample were slightly older than those in Gemini (26.4 months compared with 20.6 months, $p< 0.001$). There were slightly more boys in the NDNS sample than Gemini (53.6% vs 49.5%, $p= 0.14$), less children of white ethnicity (85% vs 95.1%, $p< 0.001$) and fewer mothers of higher SES (40.9% vs 46%, $p< 0.001$).

Table 4.1: Sample characteristics in Gemini and the National Diet and Nutrition Survey NDNS

Characteristic	Mean (SD) or *n* (%) Gemini (*n*= 2336)	NDNS (*n*= 386)	*p*-value
Age at diet diary completion (m)	20.6 (1.1)	26.4 (8.8)	**<0.001**
Weight at birth (kg)	2.5 (0.5)	-	
Weight SDS at birth[a]	-0.5 (0.9)	-	
Gestational age (wks)	36.2 (2.5)	-	
Feeding method 0-3 months (n (%))[b]			
Breast-fed infants	1468 (62.8)	-	
Bottle-fed infants	868 (37.2)	-	
Sex (n (%))			0.14
Boys	1157 (49.5)	207 (53.6)	
Girls	1179 (50.5)	179 (46.4)	
Ethnicity (n (%))			**<0.001**
White	2222 (95.1)	328 (85.0)	
Non-white	106 (4.9)	58 (15.0)	
Socio-economic status (n (%))[c]			**<0.001**
High	1056 (46.0)	158 (40.9)	
Intermediate	370 (16.1)	79 (20.5)	
Low	872 (37.9)	149 (38.6)	

Abbreviations: NDNS, National Diet and Nutrition Survey; SD, standard deviation; m, months; kg, kilograms, wks, weeks; %, percentage

[a] Weight SDS references children's weights against the UK population mean (weight SDS=0) in 1990(Cole et al. 1995) for the child's age at measurement, sex, and gestational age. A weight SDS >0 indicates higher weight, and a weight SDS <0 indicates lower weight compared to British children of the same age, sex and gestational age in 1990.

[b] The proportion of infants breast-fed in the first three months from birth was obtained with the question "which feeding method did you use in the first 3 months?" with response options ranging from 1=entirely breast feeding, 2=mostly breast some bottle, 3=equally breast and bottle, 4=mostly bottle some breast, 5=almost entirely bottle, 6=entirely bottle feeding. Categories 1-5 were classified as 'breast-fed' and category 6 as 'bottle-fed'.

[c] Classified using the Office for National Statistics National Statistics Socio-economic Classification (NS-SEC)(Office for National Statistics 2005) and grouped into higher (higher and lower managerial and professional occupations), intermediate (intermediate occupations, small employers and own account workers) and lower SES (lower supervisory and technical occupations, (semi)routine occupations, never worked and long-term unemployed).

4.4.2 Dietary intake in the Gemini sample

4.4.2.1 Energy and nutrient intakes

The average daily energy and nutrient intakes from food, drinks and supplements for the Gemini sample are shown in **Table 4.2**. Daily energy intake was 4330 kJ and this comprised 12% energy from protein; 51% energy from carbohydrate; and 37% energy from fat. Children consumed 18% of energy from saturated fat, 27% of energy from sugars and consumed 8g/d of fibre. Vitamin D intake was 2.3 µg/d and iron intake 6.4 mg/d. Vitamin C intake was 60 mg per day, calcium intake was 842 mg per day and sodium intake was 1148 mg/d.

Table 4.2 Energy and nutrient intake from food, drinks and supplements for children in the Gemini sample and the NDNS

Dietary Intake	**Gemini 21 months** (*n*= 2336) (mean (SE))	**NDNS[a] 18-36 months** (*n*= 386) (mean (SE))	***p*-value[b]**
Daily energy intake (kJ)	**4330** (67)	**4728** (64)	**0.001**
Fat (g/d)	42 (0.2)	43 (0.8)	0.46
Fat (%E)	**37** (0.1)	**34** (0.3)	**0.001**
Saturated fat (g/d)	20 (0.1)	19 (0.4)	0.23
Saturated fat (%E)	**18** (0.1)	**15** (0.2)	**<0.001**
Protein (g/d)	40 (0.2)	43 (0.6)	0.07
Protein (%E)	**12** (0.04)	**15** (0.1)	**<0.001**
Carbohydrate (g/d)	**132** (0.6)	**152** (2.1)	**<0.001**
Carbohydrate (%E)	51 (0.1)	51 (0.3)	0.05
Starch	**62** (0.4)	**77** (1.2)	**<0.001**
Starch (%E)	24 (0.1)	26 (0.4)	0.63
Total sugars (g/d)[c]	**69** (0.4)	**75** (1.6)	**<0.001**
Total sugars (%E)[c]	27 (0.1)	25 (0.4)	0.17
Dietary fibre as NSP(g/d)	8 (0.1)	8 (0.2)	0.90
Sodium (mg/d)	1148 (7.0)	1318 (24)	0.51
Vitamin C (mg/d)	60 (0.6)	73 (3.3)	0.01
Thiamine (mg/d)	0.9 (0.01)	1.0 (0.1)	0.86
Riboflavin (mg/d)	1.7 (0.01)	1.4 (0.03)	0.02
Niacin (mg/d)	**9.8** (0.1)	**19.5** (0.3)	**<0.001**
Folate (µg DFE/d)	159 (0.9)	150 (2.6)	0.13
Vitamin B-12 (µg/d)	4.2 (0.03)	3.9 (0.1)	0.77
Calcium (mg/d)	842 (4.8)	774 (15.3)	0.29
Vitamin D (µg/d)	2.3 (0.1)	2.2 (0.1)	0.51
Vitamin A (µg RAE/d)	551 (5.9)	568 (18.9)	0.64
Iron (mg/d)	6.4 (0.1)	6.4 (0.1)	0.82

Abbreviations: NDNS, National Diet and Nutrition Survey; SE, standard error; kJ, kilojoules; g/d, grams per day; %E, % energy; mg/d, milligrams per day; µg/d, micrograms per day; DFE, Dietary Folate Equivalent; RAE, retinol activity equivalent;
[a] NDNS data are weighted to account for potential differences in the probability of households and individuals being selected to take part; and the potential influence of non-response bias.
[b] P-value for difference between Gemini and NDNS on dietary intake variables. Significant differences (*p*< 0.01) are shown in bold. Analyses were adjusted for age, sex, ethnicity and socioeconomic status.

[c] Data on sugar components (non-milk extrinsic sugars and intrinsic milk sugars) were not available as it was not requested at the time HNR coded the dietary data.

4.4.2.2 Meal size and frequency

Table 4.3 shows the average meal sizes and frequencies of eating and drinking occasions (excluding water) for children in Gemini. On average children consumed 646 kJ during each consumption occasion (eating and drinking occasions combined). Meal sizes during eating occasions were larger than during drinking occasions (735 kJ versus 426 kJ). Children had approximately five eating occasions per day, and between one and two drinking occasions per day.

Table 4.3 Meal size and frequency for children in the Gemini sample and the NDNS

	Gemini (21 months old) (n= 2336) (mean (SD))	**NDNS**[a] (18-36 months old) (n= 386) (mean (SD))	***p*-value**[a]
MEAL SIZE (kJ)			
Meal size (consumption occasion)[b]	**646** (172)	**716** (208)	**<0.001**
Meal size (eating occasion)	**735** (204)	**802** (220)	**0.001**
Meal size (drinking occasion)[b]	**426** (170)	**368** (231)	**<0.001**
MEAL FREQUENCY (times per day)			
Meal frequency (consumption	6.7 (1.5)	6.6 (1.8)	0.57
Meal frequency (eating occasions)	**4.9** (1.0)	**5.3** (1.3)	**<0.001**
Meal frequency (drinking occasions)[b]	**1.7** (1.0)	**1.3** (1.1)	**<0.001**

Abbreviations: NDNS, National Diet and Nutrition Survey; SE, standard error, kJ, kilojoules
[a] *P*-value for difference between Gemini and NDNS on eating occasion variables. Significant differences (p< 0.01) are shown in bold. Analyses were adjusted for age, sex, ethnicity and socioeconomic status.
[b] Occasions in which only water were consumed have been excluded

4.4.2.3 Food and drink intakes

Table 4.4 shows the energy consumed in food and drinks within the Gemini sample. Children aged 21 months were consuming on average 3172 kJ (73.4% of their daily energy intake) from food (minus drinks consumed with food) per day, and 1158 kJ

(26.6% of their daily energy intake) from drinks. The majority (92.5%) of the sample were consuming cow's milk (as a drink or with food) at the time of diary completion, and on average this made up 23% of their daily energy intake. Very few children were still consuming breast milk (*n*= 34; 1.5%); these children were receiving 13.3% of their energy intake from breast milk. Interestingly however, a larger proportion of the sample (*n*= 309; 13.2%) were still consuming formula milk, and for those children it comprised 19.6% of their energy intake.

Table 4.4. Food and drink intakes for children in the Gemini sample at 21 months of age

Dietary Intake	**Mean (SE)**	**Range**
Daily energy intake (kJ) (*n*= 2336)	4330 (16)	1788 - 8599
Energy intake from food (kJ) (*n*= 2336)	3172 (15)	789 - 5862
%E from food (*n*= 2336)	73.4 (0.2)	28.6 - 100
Energy intake from drinks (kJ) (*n*= 2160)	1158 (10)	0 - 3231
%E from drinks (*n*= 2160)	26.6 (0.2)	0.1 – 67.2
Cow's milk intake (kJ) (*n*= 2231)	1007 (11)	3 - 3023
%E from cow's milk (*n*= 2231)	23.0 (0.2)	0.1 – 71.4
Formula milk intake (kJ) (*n*= 309)	834 (25)	12 - 3111
%E from formula milk (*n*= 309)	19.6 (0.6)	0.5 – 64.5
Breast milk intake (kJ) (*n*= 34)	680 (83)	48 - 1638
%E from breast milk (*n*= 34)	13.3 (1.9)	0.1 – 37.2

Abbreviations: SE, Standard Error; kJ, kilojoules, %E, percentage of daily energy intake

4.4.3 Comparisons between Gemini and the National Diet and Nutrition Survey (NDNS)

4.4.3.1. Energy and nutrient intakes

Table 4.2 compares the energy, macronutrient and micronutrient intakes of the Gemini sample with the NDNS. Daily energy intakes were lower in Gemini than the NDNS (p= 0.001). Absolute intakes of fat and protein were the same in both samples, but children in the NDNS sample consumed greater amounts of total carbohydrate (152 g versus 132 g/day). This meant that although there was no difference in the %E from carbohydrate (p= 0.05), starch (p= 0.63), sugars (p= 0.17) or fibre (p=0.90), the %E from fat (37%) and saturated fat (18%) were higher in Gemini than the NDNS (34% and 15% respectively; p-values <0.01), and %E from protein (12%) was lower than in the NDNS (15%; p< 0.001). With the exception of niacin (p< 0.001) where intakes were almost double in NDNS compared to Gemini, there were no significant differences between the two samples in the intake of any micronutrients. Vitamin D and iron intake in Gemini and the NDNS sample were almost identical.

4.4.3.2 Meal size and frequency

Table 4.3 compares the meal size and frequency of eating and drinking occasions within the Gemini sample with those from the NDNS. Regardless of how meal size was defined, children in Gemini consumed less energy per meal than children in the NDNS (p-values< 0.01 for all meal size variables). Interestingly, children in Gemini ate less frequently (4.9 times per day compared to 5.3 times per day, p< 0.001) but drank more frequently (1.7 times per day versus 1.3 times per day, p< 0.001) than children in NDNS. This meant that there was no difference between the two samples in the overall frequency of consumption (eating and drinking occasions combined) (6.7 and 6.6 times per day respectively, p= 0.57).

4.4.4 Comparisons with Dietary Reference Values

Table 4.5 compares UK DRVs to the daily energy intake and nutrient intakes (including intake from supplements) of children in Gemini. The average daily energy intake for the sample as a whole exceeded the level recommended by the SACN for children aged two years by 280 kJ (p<0.001). The majority (63%) of children consumed more energy than recommended, but this meant that over one third of children (37%) consumed less than the recommended amount of energy per day. Protein intake was almost three times higher than the RNI (40 g versus 15 g, p<

0.001), with just 0.1% of children failing to meet the protein RNI. Fibre intake was almost half that which is recommended (8 g/d rather than 15 g/d; $p < 0.001$).

With the inclusion of supplements, the intake of all micronutrients, except vitamin D and iron, met the RNIs set by the Department of Health (Department of Health 1991). Vitamin D intake was less than half that recommended, even with supplementation ($p < 0.001$) and just 6.8% of the sample met the RNI. Only 30% of the sample met the RNI for iron, with 6.3% below the LRNI. The RNI set for sodium (Scientific Advisory Committee on Nutrition 2003) was exceeded by almost all children (98.8% of the sample). The average sodium intake was more than double the RNI, and in many other cases, including Vitamin C, riboflavin, folate, calcium and vitamin B-12, micronutrient, intakes also far exceeded recommended levels.

Table 4.6 shows the daily energy intake and nutrient intakes (excluding intake from supplements) of children in Gemini compared with DRVs. Even without supplementation all micronutrient intakes, except Vitamin D and iron, exceeded RNIs. Vitamin D intake increased with supplementation ($p < 0.001$), as did iron intake ($p < 0.001$), but only 10.9% and 84.5% of children (for Vitamin D and iron, respectively) exceeded the LRNI when supplements were not included. Few children were found to be taking supplements ($n = 173$; 7.4%), and among those that were, the average intake of Vitamin D was 6.8 µg/d, compared to 2.3 µg/d among the full diary sample. However, despite this 54.9% of those taking supplements still did not meet the RNI, and 31.8% did not meet the LRNI for Vitamin D. Iron intake among those taking supplements was 8.5 µg/d; higher than among the full sample (6.4 µg/d), but nevertheless the RNI was still not met by 60.7% and the LRNI by 2.9%.

Table 4.5. Energy, macronutrient and micronutrient intake[a] from food, drinks and supplements for children in the Gemini sample aged 21 months; and comparisons with Dietary Reference Values (DRVs)

Nutrient	DRV	LRNI	Mean[a] (% of DRV)	% of sample with intakes below DRV	% of with intakes below LRNI	SE	25th percentile	75th percentile	Min-Max	*p*-value[g]
Daily energy intake (kJ)	**4050**[b]	-	**4330**(107)[b]	37	-	67	3794	4786	1770-8569	**<0.001**
Total fat (g/d)	-	-	42	-	-	0.2	35	49	13-86	-
Total fat (%E)	-	-	37	-	-	0.1	34	40	18-57	-
Saturated fat (g/d)	-	-	20	-	-	0.1	16	24	3-42	-
Saturated fat (%E)	-	-	18	-	-	0.1	15	20	4-33	-
Protein (g/d)	**14.5** [c]	-	**40** (276)	0.1	-	0.2	34	45	11-76	**<0.001**
Protein (%E)	-	-	12	-	-	0.04	11	14	7-20	-
Total carbohydrates (g/d)	-	-	132	-	-	0.6	114	148	52-269	-
Total carbohydrates	**50**[d]	-	**51**(102)	-	-	0.1	47	55	26-77	**<0.001**
Starch	-	-	62	-	-	0.4	50	72	13-167	-
Starch (%E)	-	-	24	-	-	0.1	21	27	6-58	-
Total sugars (g/d)	-	-	69	-	-	0.4	57	80	21-165	-
Total sugars (%E)	-	-	27	-	-	0.1	24	30	8-49	-
Dietary fibre as NSP(g/d)	**15**[d]	-	**8** (53)	-	-	0.12	6	9	1-20	**<0.001**
Sodium (mg/d)	**500**[e]	200	**1148** (230)	1.2	0	7.0	914	1350	221-2727	**<0.001**

Vitamin C (mg/d)	**30**[c]	8	**60** (200)	13.5	0	0.6	38	77	11-226	**<0.001**
Thiamine (mg/d)	**0.5**[c]	0.23	**0.9** (180)	1.7	0	0.01	0.7	1.0	0.4-5.8	**<0.001**
Riboflavin (mg/d)	**0.6**[c]	0.3	**1.7** (283)	1.1	0	0.01	1.3	2.0	0.3-6.0	**<0.001**
Niacin (mg/d)	**8**[c]	4.4	**9.8** (123)	32.1	1	0.1	7.5	11.3	2.4-61.3	**<0.001**
Folate (µg DFE/d)	**70**[c]	35	**160** (227)	0.3	0	0.9	130	184	46.7-429	**<0.001**
Vitamin B-12 (µg/d)	**0.5**[c]	0.3	**4.2** (840)	0.2	0	0.03	3.1	5.2	0.3-13.4	**<0.001**
Calcium (mg/d)	**350**[c]	200	**842** (241)	1.3	0.1	4.8	686	973	187-1905	**<0.001**
Vitamin D (µg/d)	**7**[c]	3.9[f]	**2.3** (33)	93.2	84.2	0.1	0.9	2.5	0-16.3	**<0.001**
Vitamin A (µg RAE/d)	**400**[c]	200	**551** (138)	27.6	1.6	5.9	389	639	72-4265	**<0.001**
Iron (mg/d)	**6.9**[c]	3.7	**6.4** (93)	69.8	6.3	0.1	4.8	7.3	1.1-96.1	**<0.001**

Abbreviations: DRV, Dietary Reference Value; LRNI, Lower Reference Nutrient Intakes; %, percentage;; SE, Standard Error; kJ, kilojoules; g/d, grams per day; %E, percentage of daily energy intake; NSP, Non-Starch polysaccharides; mg/d, milligrams per day; µg/d, micrograms per day; DFE, Dietary Folate Equivalent; RAE, retinol activity equivalent;

[a] Mean intake including supplements

[b] DRV for daily energy intake is based on the Scientific Advisory Committee on Nutrition (2011) estimated average requirements (EARs) for children two years of age and the mid-point of DRV for males (4201 kJ/d) and females (3899kJ/d) (Scientific Advisory Committee on Nutrition 2011)

[c] RNI for children 1-3 years of age from Department of Health, *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*, HMSO, 1991(Department of Health 1991)

[d] RNI for children 2-5 years of age from Scientific Advisory Committee on Nutrition (2015)(Scientific Advisory Committee on Nutrition 2015a)

[e] RNI for children 1-3 years of age from Scientific Advisory Committee on Nutrition (2003)(Scientific Advisory Committee on Nutrition 2003)

[f] Calculated as 75% of Estimated Average Requirement (5.25µg/d)

[g] P-value for difference between mean intake of children in the Gemini sample and the DRV. Significant differences (p< 0.01) are shown in bold.

Table 4.6. Micronutrient intake from diet only (excluding supplements) for children in the Gemini sample aged 21 months; and comparison with DRVs

Nutrient	RNI	LRNI	Mean[a] (% of RNI)	% of sample with intakes below DRV	% of with intakes below LRNI	SE	25th percentile	75th percentile	Min-Max	*p*-value[e]
Sodium (mg/d)	**500**[b]	200	**1148** (230)	1.2	0	7.0	914	1350	221-2727	**<0.001**
Vitamin C (mg/d)	**30**[c]	8	**58** (193)	14.6	0	0.6	37	73	11-226	**<0.001**
Thiamine (mg/d)	**0.5**[c]	0.2	**0.9** (180)	2.0	0	0.004	0.7	1.0	0.36-2.1	**<0.001**
Riboflavin (mg/d)	**0.6**[c]	0.3	**1.6** (266)	1.1	0	0.01	1.3	1.9	0.3-3.6	**<0.001**
Niacin (mg/d)	**8**[c]	4.4	**9.4** (117)	34.7	1.0	0.07	7.4	10.8	2.4-61.3	**<0.001**
Folate (µg DFE/d)	**70**[c]	35	**159** (229)	0.4	0	0.9	129	184	43-429	**<0.001**
Vitamin B-12 (µg/d)	**0.5**[c]	0.3	**4.2** (840)	0.2	0.1	0.03	3.1	5.2	0.3-13.4	**<0.001**
Calcium (mg/d)	**350**[c]	200	**841** (240)	1.3	0.1	4.8	686	973	186-1905	**<0.001**
Vitamin D (µg/d)	**7**[c]	3.9[d]	**1.9** (27)	96.9	89.1	0.04	0.8	2.1	0-12.8	**<0.001**
Vitamin A (µg RAE/d)	**400**[c]	200	**525** (131)	29.7	1.7	5.5	382	612	72-4625	**<0.001**
Iron (mg/d)	**6.9**[c]	3.7	**6.2** (90)	70.6	6.5	0.04	4.8	7.2	1.1-14.6	**<0.001**

Abbreviations: RNI, Reference Nutrient Intake; LRNI, Lower Reference Nutrient Intakes; %, percentage; SE, Standard Error; mg/d, milligrams per day; µg/d, micrograms per day; RAE, retinol activity equivalent

[a] Mean intake excluding supplements

[b] RNI for children 1-3 years of age from Scientific Advisory Committee on Nutrition (2003)(Scientific Advisory Committee on Nutrition 2003)

[c] RNI for children 1-3 years of age from Department of Health, *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*, HMSO, 1991(Department of Health 1991)

[d] Calculated as 75% of Estimated Average Requirement (5.25 µg/d)

[e] P-value for difference between mean intake of children in the Gemini sample and the RNI. Significant differences ($p < 0.01$) are shown in bold.

4.5 Discussion

4.5.1 Summary of findings

The primary aim of this study was to better understand *what* young children in the UK are eating, as well as *how* they are eating. There have been very few large-scale national studies of dietary intake in young children in the UK and given that dietary factors might contribute to weight gain and/or poor health during childhood, this study sought to fill this gap in the literature. In particular the objectives were to: i) describe the daily energy and nutrient intakes from food and drinks for children aged 21 months in the UK, ii) describe the average size and frequency of eating and drinking occasions for children aged 21 months in the UK, iii) compare the energy and nutrient intakes, and the meal size and frequency of eating and drinking occasions of Gemini twins to those of 386 children aged 18-36 months in the nationally representative NDNS rolling programme (2008-12) and iv) compare the energy and nutrient intakes of the Gemini twins at 21 months to UK public health nutrition recommendations for energy and nutrient intakes at two years of age in order to assess whether children are meeting dietary guidelines.

The energy and nutrient intakes of children aged 21 months in the UK have been described in the current study and compared with a sample of singletons aged 18-36 months in the UK to show that the Gemini dietary data is comparable to that of a nationally representative sample (NDNS). Children in the Gemini sample had lower energy intakes than children in the NDNS, but this is unsurprising given that the NDNS sample were slightly older, and are therefore likely to have higher energy needs. Absolute intakes of fat and protein were virtually the same in both samples, but children in the NDNS sample consumed greater amounts of total carbohydrate (152 g versus 132 g/day) which increased the energy intake of the NDNS and resulted in slight differences across the two samples in the %E from other macronutrients. There was no difference in the %E from carbohydrate, starch, sugars or fibre but Gemini children subsequently had a greater %E from fats and from protein. Although clinically significant, these differences were relatively small (3%) and there were no significant differences between the two samples in the intake of any micronutrients except for niacin. The much higher niacin intake in the NDNS might be explained by differing sources of protein; niacin is found in protein-rich foods such as meat but we know that a large proportion of the protein intake in Gemini was consumed in milks (Pimpin et al. 2015). As the NDNS sample were older than the Gemini sample one might expect them to be consuming less milk, and instead may have been consuming protein from meats and fish. Exploring the sources from which protein is consumed in early life is an area worthy of further research.

In 1994, ALSPAC found that the daily intakes of energy and protein for children at 18 months of age in England were higher than recommended for children two years of age (Cowin & Emmett 2007). As with Gemini, dietary data were collected using three day diaries, and the sample was also large, with 1026 children aged 18 months. It appears, despite profound changes in the food environment, and the recorded increases in obesity prevalence in young children since ALSPAC (Stamatakis et al. 2010), that there have been relatively few changes in nutrient intakes in young children. Average energy intakes were slightly higher in ALSPAC than those reported in the current study (4530kJ in ALSPAC vs 4330kJ in Gemini). However, the differences between the two studies are quantitatively small and it is difficult to draw robust conclusions about secular trends as the two studies are different. There were differences in the participants, for example, in ALSPAC the children were 18 months old and from South West England, but in Gemini the children were 21 months old and from across England and Wales. There were also differences in the dietary assessment methodology as parents of children in Gemini received a portion size booklet and posted the diet diaries back to the research team, whereas in ALSPAC parents did not receive a portion guide, and parents were invited to a clinic visit where a trained assistant checked the diaries for completeness and clarified any uncertainties. Diaries were also coded using different dietary software; Gemini used Diets in Nutrients Out (DINO) and ALSPAC used Data in Diet Out (DIDO) (Golding et al. 2001).

Dietary data from the Diet and Nutrition Survey for Infants and Young Children (DNSIYC) collected in 2011 also showed that children aged 12-18 months were consuming more energy than recommended. On average they consumed 2916 kJ per day, and this equated to 131% of the recommended intake for children aged 12-24 months (Gibson & Sidnell 2014). Within the Gemini sample at 21 months of age children were exceeding the DRV for daily energy intake by 7%, and children in the rolling programme of the NDNS aged 18-36 months were exceeding the DRV by 17%. Taken together, these samples suggest that at a population level, young children in the UK are at risk of excess weight gain.

The meal size and frequency of eating and drinking occasions of children in Gemini suggest that at 21 months old children eat approximately five times per day, and drink one to two times per day. Eating occasions are more strongly associated with higher energy intake than drinking occasions. Children aged 18-36 months from the NDNS consumed larger meal sizes overall (eating and drinking occasions combined) than children in Gemini, which may reflect their higher energy needs given their older age. They consumed more energy per eating occasion, but less energy during drinking occasion. Younger toddlers, such as those in Gemini (21 months of age), were still consuming large quantities of milk, but children in the NDNS (18-36 months) were older and therefore more likely to have been weaned off milk and onto a solid-food based diet. This is also mirrored in the frequency parameters; children in Gemini drank more often than children in the NDNS, but they ate less frequently, probably reflecting the different dietary behaviours at different ages. Overall though, consumption frequency (eating and drinking frequency combined) did not differ between the two samples.

This study has shown that the majority of children's intake at 21 months of age is consumed in food, rather than drinks. However, a substantial proportion (26.6%) of daily energy intake is consumed in drinks, and predominantly cow's milk. Interestingly, just 1.5% of Gemini children were still consuming breast milk at 21 months of age but a reasonably large proportion of children in the sample (13%) were still consuming formula milk. This is at an age when cow's milk can be consumed (from 12 months of age) (Committee on Nutrition 1983) and follow-on formula is unnecessary (Department of Health 2008; World Health Organisation 2005), so the reasons behind this extended use of formula are worthy of further exploration. The 2011 UK Diet and Nutrition Survey of Infants and Young children (DNSIYC) found 39% of children aged 12-18 months were consuming formula milk (Lennox et al. 2013) but the larger proportion is likely to reflect the younger age group in the DNSIYC within which the full transition to solid food won't have taken place yet.

Parents seem to be offering their toddlers high quantities of milk, in addition to food but this is understandable given that there is currently limited guidance for parents on appropriate quantities of milk for toddlers. The Infant and Toddler Forum have some guidance on recommended portion sizes for milk; between 100-120ml of cow's milk on three occasions during a day (The Infant and Toddler Forum 2015). Whole cow's milk contains 252 kJ per 100ml, which would equate to a recommended intake of 756–907 kJ per day. Based on this, the average intake of 1007 kJ observed in Gemini is higher than recommended, and not only this but the age range for the guidance is wide (one to four years of age). It seems inappropriate to be offering the same advice about milk to parents of one year olds and four year olds. More tailored guidance based on age and stage of development is required. Further research is needed to explore possible explanations for children continuing to consume large quantities of milk at an age when weaning should be close to completion. The large proportion of children consuming formula milks, in addition to cow's milk is of particular interest as it is possible that this additional milk may result in over-consumption. It is therefore important to explore the impact of high milk intake, and more specifically, the impact of extended formula milk feeding during toddlerhood on daily energy intake and weight gain.

When compared with the DRV for children aged two years, the average daily energy intakes of the Gemini sample were found to be 7% higher than recommended. Given that the recommendations are for children aged two years, and the Gemini sample are 21 months old, the sample should in fact have slightly lower energy requirements than the recommended intake. In addition, while the mean difference may appear relatively small (280kJ per day) there is the potential that if this is sustained during childhood, it will lead to excessive weight gain. The 3500-kilocalorie 'rule' is widely accepted and it states that an expected fat gain of one pound (approximately 0.45 kg) will occur with a 3500-kcal (approximately 14,650 kJ) excess in energy intake (Wishnofsky 1958). This would suggest that with an excess of 280 kJ per day, within just two months children would consume 17,000 kJ and gain more than one excess pound (0.45 kg) in weight. It is easy therefore to see how this additional energy each day cumulates over time and might lead to excess weight gain in these young children. Previous comparisons of the NDNS sample with DRVs (Gibson & Sidnell 2014; Bates et al. 2014) show similar results, so excessive energy intakes in young children in the UK are a widespread concern.

The RNI of protein for children aged one to three years in the UK is 14.5 g/day, and this is the level estimated to cover the requirements of 97.5% of this age group. From a population perspective 14.5 g/d is at the right tail end of the normal distribution, and given that both the Gemini sample and the NDNS sample were consuming almost three times the RNI on average, and a high proportion of children exceeded the level sufficient for their requirements, this essentially reflects excess intake in the two samples. The RNI implies that the intake level equates to deficiency in 2.5% of the population, however, only 0.1% of the Gemini sample had intakes of protein below the RNI. Just two children out of 2336 could potentially be categorised as protein deficient based on population requirements. That is assuming this was a true measure of habitual intake and did not reflect an unusually low intake, perhaps due to illness or unrepresentative protein intakes over the three measurement days. Intake beyond 14.5g /day is unnecessary and high protein intakes among young children in the UK is a concern given the evidence linking protein intake with excess adiposity and weight gain in children (Eloranta et al. 2012; Escribano et al. 2012). A longitudinal study by Gunther et al (2007) also demonstrated that a high protein intake during the complementary feeding period (12-24 months) was associated with higher BMI SDS and percentage body fat at seven years of age (Günther et al. 2007). The dietary data from the Gemini sample has been used to show that higher protein intake is associated with increases in both BMI and weight up to the age of five years (Pimpin et al. 2016). Importantly, it was protein consumed from dairy rather than other animal-based protein or plant-based protein that was driving the increases in weight gain (Pimpin et al. 2015). We also know that within this sample almost a quarter of children's energy intake was consumed in milk (Pimpin et al. 2013) and many children (13%) were still consuming formula milk at 21 months of age. This suggests that Gemini children may have been consuming too much milk and it was milk contributing to the excess daily energy intake (Syrad et al. 2015).

Average fibre intake was just half the recommended amount (8 g vs 15 g per day). It is important for children to consume high fibre diets. Ensuring children consume sufficient fibre will help to reduce conditions such as constipation, and will also help to establish healthy habits for later in life when conditions such as colon cancer, coronary heart disease and obesity can result from low fibre diets (Buttriss & Stokes 2008). All micronutrient intakes except vitamin D and iron were higher than recommended in the current study and high intakes should therefore be monitored as part of population risk assessments. Sodium intake within Gemini and NDNS in particular, was a cause for concern, being almost three times higher than recommended; this is especially concerning given that the sodium intakes reported here are likely to be underestimated as salt added during cooking and at the table is usually poorly reported (McLean 2014). High sodium intakes during early life may set taste preferences for the future (Stein et al. 2012). A prospective study exploring associations between early exposure (two to six months) to sodium and later preference (36 to 48 months) found that infants that had been exposed to starchy table foods (a source of sodium) at six months preferred salty solutions given in a randomised double-blind trial. They were also more likely to lick salt from the surface of foods at pre-school age (36-48 months) and eat plain salt (Stein et al. 2012). High sodium intake increases the risk of raised blood pressure and adverse cardiovascular health in adults (Brown et al. 2009). Although parents are advised not to add salt to food they prepare for young children, most salt in the diet comes from processed foods (Scientific Advisory Committee on Nutrition 2003) so as children move away from specially prepared foods and start eating meals with the rest of the family there is a real risk of high intakes of salt.

Iron and Vitamin D intakes were low in the current sample and in the NDNS sample. Almost 70% of children did not meet the recommended intakes of iron; and even with the inclusion of supplements the average vitamin D intake (2.3 µg/d) fell far short of the seven micrograms set by the Department of Health. Less than 7% of children met the recommended Vitamin D level, and insufficient intake of vitamin D has been associated with poor health including musculoskeletal disorders such as rickets (Scientific Advisory Committee on Nutrition 2015b; Holick 2004; Baker & Greer 2010). Supplements were only taken by 7% of children and for these children intakes of vitamin D did increase, but the majority of children (84.2%) were still not meeting the LRNI for vitamin D. The DNSIYC, conducted in 2011, also found levels of Vitamin D were below those recommended for children aged one to three years (3.8 µg per day compared to the 7 µg recommended) so while levels were higher than those observed in Gemini (2.3 µg per day), and the NDNS (1.5 µg per day), they still fall short of recommendations. Low vitamin D intake is a widespread issue among young children within the UK and the findings here reflect what is already known; that diet alone is unlikely to provide young children with sufficient intakes of vitamin D. Vitamin D is found in sunlight, but this is limited in the UK, and dietary sources of vitamin D are limited and insufficient to ensure adequate supplies. This is especially true for young children as some of the best sources, such as oily fish, are foods not commonly or regularly consumed by young children. This is the reason for the UK government recommendations for children aged six months to five years to take a daily supplement containing vitamin D (Department of Health 2010b). Despite this, it seems the majority of children are not being given this. Very recently the SACN (2015) (Scientific Advisory Committee on Nutrition 2016) have recommended intakes of Vitamin D are increased from 7 µg/d to 10 µg/d for children aged one to four years. This means that almost all children (96.9%) in the current study would fall below the revised recommended intake.

In addition to low intakes of vitamin D there were children (6.3%) not meeting the LRNI for iron and a large proportion (70%) not meeting the RNI. The low vitamin D and iron intakes observed in Gemini were also found in the NDNS sample in which children were not meeting the recommended intakes (Gibson & Sidnell 2014; Bates et al. 2014). Comparing these estimates with data from ALSPAC in 1994 (Ness 2004) however, population intakes of vitamin D and iron have both increased among toddlers, as at 18 months children consumed on average just 1.5 µg/d of vitamin D respectively, and 5.3 mg of iron respectively (Cowin & Emmett 2007). This suggests there has been an increase in the uptake of supplementation, and/or the consumption of more fortified milks and foods which only came into widespread use around 1997 (Wharton 1997).

Iron intake among children in the DNSIYC in 2011 (6.5 mg per day) was also comparable to that observed in Gemini (6.4 mg per day) but below the recommended intake of 6.9 mg per day. Nevertheless, intakes are still lower than recommended and suggest that parents of young children may need more education and information around recommended intakes of vitamin D and iron, and the food sources within which these micronutrients can be found.

4.5.2 Implications

The dietary intakes in the Gemini twin study have been shown to be comparable to those of the nationally representative NDNS. This demonstrates that Gemini is a valuable resource for studies of diet and health outcomes, and means that I am able to use Gemini data to answer my research questions.

The study has provided an indication of *what* and *how* young children in the UK are eating and drinking, and this data can be used to determine the role of dietary intake and eating patterns in weight gain. By drawing comparisons with public health nutrition recommendations for energy and nutrient intakes at two years of age, I have been able to exploit this dataset to explore the aspects of young children's diets that are in excess and in deficit. As a result I have been able to highlight where dietary changes may be required. Within the UK, children's diets are slightly too high in energy and they are consuming excess protein. Sodium intake is also too high and likely to be due to the consumption of processed foods. Therefore parents need to be made aware that many processed foods contain high levels of salt. They may need more guidance on checking food labels, choosing lower salt options, limiting processed food and limiting the intake of high salt foods such as ham and cheese. The Infant and Toddler Forum provide guidance for children aged one to four years on suggested portions of ham (0.5–1.5 small slices, or 1.5-4 wafer thin slices) and cheese (e.g. 2-4 tablespoons as a pizza topping or in a sandwich) (The Infant and Toddler Forum 2015) but many parents may not be aware of this guidance, and the guidance is for a relatively wide age range.

Overall, micronutrient intake among young children in the UK is sufficient. The exceptions are iron and vitamin D which warrant special attention as intakes are low, and far lower than recommended. It must be kept in mind that the intakes reported in the current study are from diet alone and sun exposure also increases vitamin D (Pearce 2010). We are unable to conclude that the children in this study were deficient in vitamin D as we do not have a measure of the amount of vitamin D absorbed from the sun. Nevertheless, it is still recommended that children aged six months to five years of age are given a vitamin D supplement. Therefore, children's vitamin D and iron intake could be increased through supplementation, either directly in the form of supplements, of via the intake of fortified foods. In the UK, free vitamins should be available to young children through the Healthy Start (HS) Scheme which provides low-income families in the UK with fixed-value food vouchers and vitamin coupons for eligible women and young children (Department of Health 2010a). A relatively recent qualitative study however found that among 107 families eligible for free supplementation, only 10% were making use of the free vitamins as they were not aware that they were available to them (Jessiman et al. 2013). Increasing awareness of eligibility for vitamin supplements among parents is important and could help to increase the intake of Vitamin D of young children within the UK. Many toddler milks and foods are now fortified with vitamin D and iron but there is also a need to provide more guidance to parents on identifying foods that are good sources of iron and vitamin D. Parents could be offered advice on how to encourage their children to eat food types that will help to increase levels of vitamin D and iron, for example offering a varied diet with reduced intakes of milk and increased intakes of oily fish and meat, as well as foods that have been fortified with vitamin D and iron.

4.5.3 Strengths and limitations

The dietary intakes and eating behaviours of children described in the current study have been derived from the largest contemporary dietary dataset for children of this age in the UK. The ability to generalise the results to all children is limited because the data comes from a twin sample; twins are often born prematurely and are usually small for gestational age. They differ from singletons in that they grow up with a person of the exact same age and are often treated as a “pair” (Koenig et al. 2010). However, this study has demonstrated that the diets of children in the Gemini sample appear to be largely representative of the UK population; reflected in the similarities between the dietary intakes of the Gemini children and those in the nationally representative NDNS sample. Gemini therefore provides a valuable resource for exploring the role of diet in weight and health outcomes, and a valuable resource for me to explore the aims of this thesis. However, there are methodological differences between the Gemini sample and NDNS sample that must be considered when drawing conclusions. There were more children of white ethnicity and higher SES in Gemini than the NDNS and these differences in sample characteristics might account for some of the differences in dietary intakes observed between the two samples. For example, Gemini children were shown to have lower sodium intakes than children in the NDNS and this suggests they may have potentially healthier diets, as one might expect in a more highly educated sample (Darmon & Drewnowski 2008). Gemini is also a voluntary cohort of families with twins, who consented to participate in the study with full information about its aims and objectives (i.e. studying influences on early growth); whereas the NDNS is a random sample of parents with children that have been invited to take part. In addition, children in the NDNS were slightly older than those in Gemini, and some of the differences in eating behaviours (meal frequency of eating versus drinking occasions for example) may be due to the fact that Gemini children are younger and still having more frequent milk feeds than those in the NDNS. The data collection and analysis method used in both samples was largely the same; unweighed diet diaries were used and nutrient and energy intakes of both samples were computed using the same dietary assessment programme (DINO). This meant measurement and analytical differences are likely to have been minimised. However, the Gemini data were collected over three days (two week days and one weekend day) rather than the four consecutive days (which did not necessarily include the weekend) in the NDNS. While both purport to reflect habitual intake, this may have meant there was greater variation in intake in the former sample. Also the relatively short recording period for both studies may not reflect habitual diet accurately (Bingham et al. 1994). Young children’s eating tends to be erratic and therefore just three or four days of assessment may not capture their diets adequately.

There are other limitations to this study. The reporting of dietary intake might have been influenced by the twin nature of the sample; the dietary intakes collected come from a parent's report of both children's intakes, and it is possible that parents found it less onerous to report the same intakes for both twins. This may lead to correlated measurement error. There were also differences between those with dietary data and the full Gemini sample **(Chapter 3)**. The diary sample included slightly more girls (51.5%) than boys, a higher proportion of families of white ethnicity and higher educational status and a lower proportion of infants were breast fed in the first three months. However, the magnitude of differences was small and therefore unlikely to greatly affect the generalizability of the findings.

Three day, unweighed food and drink diaries are an accurate method for assessing energy intake in young children when compared with weighed food records and have been validated against the doubly labelled water method of energy expenditure (Burrows et al. 2010; Lanigan et al. 2001). **Chapter 3** however demonstrated that within the Gemini sample some children's intakes were classified as under (12.4%) and over (11.9%) reported. Misreporting in this dietary data sample may have influenced findings, although the prevalence of misreporting was relatively small (24.3%).

4.5.4 Conclusions

This study demonstrates that young children in the UK have daily energy intakes higher than recommended, as well as high protein intakes, both of which are implicated in weight gain. Children are consuming excess sodium and this is a concern as they may set taste preferences for the future and increase the risk of cardiovascular health problems. The majority of young children are not consuming sufficient vitamin D, and iron intake is also lower than recommended, even among those consuming supplements. Vitamin D supplementation appears to be required by the majority of toddlers in the UK. Parents may need more guidance and support on appropriate types, amounts and varieties of foods and drinks in order to develop healthy eating practices in early life.

CHAPTER 5. THE ROLE OF APPETITE IN FORMULA MILK AND FOOD INTAKE IN EARLY LIFE[j][k]

5.1 Background

During infancy milk is a primary source of energy, but during toddlerhood a transition is made from milk feeding to solid food. This transitional period has never been explored in relation to appetite. Given the importance of early diet on later eating habits, health and weight, there is a need to understand whether appetite plays a role in what and how children eat when they are making a transition from milk to solid food.

Chapter 4 demonstrated that children aged 21 months in the Gemini cohort consumed almost 25% of their energy intake in milks. In addition, a reasonably large proportion (13%) of children still consumed formula milk at 21 months of age, despite it being recommended that the transition from a primarily milk-based diet to a modified version of the family diet should occur by this stage. Beyond 12 months of age infant formula, follow-on formula and growing up milks are not needed (Department of Health 2008; European Food Safety Authority 2013; World Health Organisation 2005). There is also no evidence to suggest that toddler milks are superior to cow's milk for babies over one year of age (UNICEF UK Baby Friendly Initiative 2010). In fact, The Department of Health have stated that "dispensing fortified (or "Picky Eating") formula milk may ensure nutrient intake for the short term, but does not help the child to acquire the appropriate eating skills and establish a healthy eating habit in the long run" (pg 6, Department of Health 2012). With this is mind it is important to establish why children continue to consume toddler milks beyond the recommended age.

The Feeding Infants and Toddlers (FITS) study (Fox et al. 2004) conducted in 2002 reported that 1.5% of 3,022 toddlers aged 19-24 months were consuming formula milk. Given that formula and follow on milk have become more heavily marketed in recent years, it is not surprising that formula feeding into later toddlerhood appears to have become more common. In line with this, within a slightly younger sample - the

[j] Data from this chapter has been published in a paper in Archives of Diseases in Childhood (Syrad, van Jaarsveld, et al. 2015)
[k] The peer-review process resulted in an acknowledgement of reverse causation; that parents may inadvertently be filling their children up with milk and as a result they lose interest in food.

2011 UK DNSIYC found that 39% of children aged 12-18 months were consuming formula milk (Lennox et al. 2013); although this much higher percentage may reflect the considerably younger age range.

For children beyond 12 months who are consuming a varied diet and foods that are good sources of iron and vitamin D such as meat and fish, there do not appear to be benefits of fortified follow-on milk, as opposed to cow's milk (Michaelsen 2000). There is also the possibility that if given in addition to food, follow-on milks may provide excess energy and contribute to obesity risk. Another issue is that high milk intake has been associated with high protein intake; and higher protein intake has been linked to excessive early weight gain in a number of studies (Escribano et al. 2012; Günther et al. 2007), including the Gemini children (Pimpin et al. 2015; Pimpin et al. 2016). It is therefore important to understand whether extended formula milk feeding might be associated with increased energy intake and higher weight gain during childhood.

Whilst there is an extensive literature base demonstrating that formula-fed infants tend to be heavier than breast-fed infants (Arenz et al. 2004; Owen et al. 2005), the relationship between *extended* formula milk intake (beyond 12 months of age) and weight gain during early childhood is an understudied area. It is possible that extended formula feeding could be associated with higher weight gain in children, if the milk is consumed in addition to energy from food and cow's milk, because it would increase a child's daily energy intake. The only study to my knowledge to explore relationships between extended formula milk intake and weight in early life compared 40 children that had been exclusively breast fed from zero to four months (total mean duration 4.4 months), and 36 infants that had been exclusively formula-fed from zero to four months (total mean duration 11.9 months). They found that the duration of formula feeding was not associated with weight among exclusively formula-fed infants, but among breast-fed infants who eventually went on to formula milks, those fed formula milk for longer tended to be heavier at 12 and 18 months, although this did not reach statistical significance (Butte et al. 2000). The sample was small, and differences between the groups could have been due to the initial feeding practices (i.e. infants who were breastfed for longer gained less weight) rather than a result of *extended* formula feeding. More research in this area is needed.

In addition to exploring the impact of extended formula milk feeding on energy intake and weight in children, it is also important to understand *why* children are consuming formula milk beyond the recommended age (Beyerlein & von Kries 2011). Research into parental decisions to begin formula-feeding during infancy suggests that some mothers view formula feeding as more convenient, less difficult and less embarrassing than breast feeding (Bonia et al. 2013; Colin & Scott 2002; Hoddinott & Pill 1999; Sheehan et al. 2010). However, parental decision-making in relation to the duration of formula feeding, or reasons for the continuation or termination of formula feeding have not previously been explored. Not all parents will know the current recommendations on infant feeding and even so, parents' perception of their own infant's needs may play a role in feeding behaviours (Northstone et al. 2001). There is emerging evidence that a child's appetite may influence parental feeding behaviours. Parents tend to exert more pressure on their child to eat if they perceive them to be a 'picky eater' and this has been shown in children of primary school age (Galloway et al. 2005) and pre-schoolers (Gregory et al. 2010b). It is therefore possible that during the complementary feeding period, parents adapt their feeding behaviours according to aspects of their child's appetite (Northstone et al. 2001). Qualitative studies have found that parents often describe their feeding styles as responsive to their child's appetitive traits; often varying them between different children in the family (Carnell et al. 2011; Moore et al. 2007; Zehle et al. 2007; Webber et al. 2010). The same processes may be at work when the child is moving on from a milk-based diet to a modified version of the adult diet. Young children with less avid appetites have previously been found to consume higher quantities of milk; cross-sectional analysis of data from 455 children in the Gateshead Millennium Baby Study, a United Kingdom population-based birth cohort, suggested that at 30 months of age high milk consumption was associated with poorer appetite, and 13% of mothers reported that their child preferred drinks to food (Wright et al. 2007).

The role of appetite in formula milk consumption specifically has not previously been explored. It is possible that if parents perceive their child to have a poor appetite, they may decide to continue using formula milk to compensate for perceived insufficient nutrition from solid foods. If this is the case, one might expect to see reduced food intake in formula consumers and no difference in energy intake or weight between children consuming formula milk and those who are not consuming formula milk.

5.2 Study aim

This study has three main aims: (i) establish the relationships between a child's appetite, extended formula milk consumption and total milk consumption; (ii) examine food, milk and energy intake patterns and weight gain trajectories for formula milk consumers and non-consumers; and (iii) explore mothers' reasons for continuing with formula milk until at least 21 months of age, using qualitative methods.

5.3 Methods

5.3.1 Study population

This study included 1897 children from the Gemini study, details of which can be found in **Chapter 3**. This was a mixed methods study utilising both quantitative and qualitative methods. The quantitative aspect of the study included 949 families (1897 children). The qualitative aspect consisted of semi-structured interviews with 35 mothers. Of the 130 families with children consuming formula at 21 months, 50 were selected at random using the random number generator in Microsoft Excel. They were invited by letter **(Appendix 5.1)** to participate in a telephone interview when their child was six to seven years old to explore retrospectively their decisions around formula-feeding their twin(s). The letter explained that the interview would take place over the telephone and they would be asked questions about the period during which children are given both formula milk as well as solids. Families were informed that the interview would be audiotaped. Families were then telephoned up to three times (day and evening to minimise selection bias) and if they were willing to participate, an interview was conducted at this time or arranged for a later date.

5.3.2 Measures

5.3.2.1 Appetite

All subscales from the CEBQ-T (Wardle et al., 2001) were used in this study, details of which can be found in **Chapter 3**. Higher scores for Enjoyment of Food [EF], e.g. "My child loves food", Food Responsiveness [FR], e.g. "My child's always asking for food" and Emotional Overeating [EO], e.g. "My child eats more when anxious" indicated a more avid appetite. Higher scores for Satiety Responsiveness [SR], e.g. "My child gets full up easily", Slowness in Eating [SE], e.g. "My child eats slowly" and Food Fussiness [FF], e.g. "My child refuses new foods at first" indicated a less avid appetite.

5.3.2.2 Dietary intake

Dietary intake was derived from the three day diet diaries (described in **Chapter 3**).

5.3.2.2.1 Formula consumption

Children were characterised as formula consumers (daily energy intake from formula or follow-on milk >0 kJ) or non-consumers. The average total daily energy intake from formula milk, average number of formula milk drinks per day, and average energy intake per formula milk drink was calculated for consumers. The term ‘formula’ will be used to refer to both formula milk and follow-on milk throughout this study.

5.3.2.2.2 Daily food and drink intake

Dietary data were also used to estimate percentage of daily energy intake (%E) from food, cow’s milk and total milks.

5.3.2.2.3 Daily energy intake

Daily energy intake (average total kJ per day) was computed for each child and summarised for the sample.

5.3.2.3 Anthropometrics and demographics

Chapter 3 describes the anthropometric measurements and demographics collected within Gemini. This study used weight and weight SDS at two years of age, and weight gain from two to five years of age as dependent variables.

Demographic data used within this study include sex, gestational age, birth weight, ethnicity (dichotomised into white and non-white) and maternal educational attainment; dichotomised into higher (university level education) and lower (no university education).

5.3.2.4 Qualitative interviews

Semi-structured interviews were carried out with 35 mothers (70% of the 50 families invited) of children that had been consuming formula at 21 months of age. They were conducted after the quantitative analysis, with the aim of exploring mothers’ reasons for continuing with formula feeding until at least 21 months of age. I developed an interview schedule (**Appendix 5.2**) consisting of open-ended questions, with prompts used as required if a parent was struggling with a response.

Example items included “Can I ask what your reasons were for giving your child(ren) formula milk at that time”. If only one twin within the family consumed formula milk (*n*= 4 families) mothers were asked about this child’s consumption, if both twins consumed formula (*n*= 31 families) mothers were asked about each child’s consumption individually. Interviews were audiotaped using a digital voice recorder. I conducted all the interviews myself, and on average they lasted 10 minutes each.

5.3.3 Statistical analyses

5.3.3.1 Identifying covariates

Gestational age, birth weight and ethnicity differed between consumers and non-consumers (**Table 5.1**) so were included in analyses as covariates. Sex and age at all data collection time points were associated with the dependent variables (CEBQ subscales, dietary intake variables, and weight) so were also included as covariates.

5.3.3.2 Quantitative analyses

I used Complex Samples General Linear Models (CSGLMs), adjusting for clustering of twins in families, to examine associations between formula feeding at 21 months and: i) appetite at 16 months of age; ii) dietary intake at 21 months of age; iii) weight at two years of age. Multi-level models were used to explore the associations between formula consumption and weight gain from two to five years. All models were fitted with formula consumption (dichotomised as yes/no) as the independent variable to compare formula consumers and non-consumers on the variables of interest. In addition, associations between appetite at 16 months and total milk consumption (percentage of energy intake (%E) from milks) were explored using CSGLMs. The p-value was set at <0.01 for all analyses.

5.3.3.2.1 Establishing relationships between extended formula milk feeding and i) appetitive traits, ii) food, milk and daily energy intake, and iii) adiposity

To explore relationships between appetitive traits and extended formula feeding, separate CSGLMs were conducted which included each of the six appetitive traits from the CEBQ as dependent variables, run as separate models. The ‘emotional overeating’ variable was transformed using the natural logarithm (ln) as the residuals from the model were not normally distributed. All models were adjusted for gestational age, birth weight, ethnicity sex, and difference in age between CEBQ completion and diet diary completion.

To explore relationships between dietary intake variables and extended formula feeding, separate CSGLMs were run with total daily energy intake, daily energy intake from food, cow's milk and total milks, as dependent variables. All models were adjusted for gestational age, birth weight, ethnicity sex, and age at diet diary completion.

Associations between extended formula milk feeding and adiposity were explored using separate CSGLMs, with two year weight and weight SDS as dependent variables. Models were adjusted for gestational age, birth weight, ethnicity, sex, and difference in age between diet diary completion and two year weight measurement.

Multilevel mixed-effects linear regression was used to explore longitudinal associations between extended formula feeding and growth between two and five years of age. All weight measurements for each child are taken into account in the model. Stata version 13 (StataCorp LP 2013) was used to run three-level hierarchical models which accounted for clustering of weight measurements within the child and family. Models regressed weight on age, sex and formula feeding (yes/no) and their interactions with age. The average growth rate within the sample was 36 g/wk and % growth increase in addition to the mean base growth rate was calculated by dividing the beta coefficient by the mean growth rate and multiplying by 100. Multi-level models examined the contribution of formula feeding (yes/no) to weekly weight gain (g and %), in addition to the mean base growth rate. The multi-level model was run with formula consumption (yes/no) as the independent variable, adjusted for sex, gestational age, birth weight and weight at two years of age to control for differences in subsequent growth rate driven by earlier weight differences.

5.3.3.2.2 Establishing relationships between appetitive traits and total milk consumption

To explore relationships between appetitive traits and total milk consumption, separate CSGLMs were conducted with %E from milks as the dependent variable, and separate models run for each of the six appetitive traits from the CEBQ as independent variables. Models were adjusted for gestational age, birth weight, ethnicity sex, and difference in age between CEBQ completion and diet diary completion.

5.3.3.3 Qualitative analyses

Content Analysis was used to interpret the qualitative data (Cole 1988) (described in **Chapter 3**). I developed the coding frame (**Appendix 5.3**) in advance based on possible responses to the question "Can I ask what your reasons were for giving your child(ren) formula milk at that time". NVivo (NVivo Qualitative Data Analysis Software. Version 10 2012) was used to code mothers' responses to this question into the pre-established categories within my coding frame.

For each mother I tallied the reasons they gave for offering formula milk and then counted the number of mothers within each of the categories. Content analysis was deemed the most suitable method of qualitative analysis for this study as I was interested in exploring mothers' perceptions of their child's eating behaviours and their own feeding decisions. Content analysis enabled me to determine the proportion of mothers reporting each of the pre-established reasons for offering formula milk. A second researcher with experience in analysing interviews used the coding frame to second code interview responses. They validated the extracted themes, and whilst there were minor differences in terminology, there were no differences in the emerging themes.

5.4 Results

5.4.1 Quantitative study

5.4.1.1 Sample characteristics

1897 children had complete data for the CEBQ, three day diet diary, two year weight, and all covariates; they constituted the final quantitative sample.
Sample characteristics for the final quantitative sample of 1897 children are shown in **Table 5.1**. Compared with non-consumers, the sample of formula consumers had significantly more parents of non-white ethnicity (9.3% vs 3%, $p < 0.001$), and the children had a significantly lower gestational age (35.65 vs 36.29 weeks, $p < 0.001$). There were no significant differences between the two groups on any other characteristic.

Table 5.1: Characteristics of the quantitative analysis sample (mean (SD) or %)

	Full quantitative sample (*n*= 1897)	**Formula consumers** (*n*= 250)	**Formula non-consumers** (*n*= 1647)	***p*-value**[a]
Sex %				
Boys	48.3	47.8	48.4	0.862
Girls	51.7	52.2	51.6	
Ethnicity %				
White	96.2	90.7	97.0	**<0.001**
Non-white	3.8	9.3	3.0	
Maternal education %				
Low	49.3	56.7	48.2	0.013
High	50.7	43.3	51.8	
Age at appetite measurement (m)	15.67 (1.05)	15.72 (0.85)	15.67 (1.08)	0.49
Age at diet diary completion (m)	20.58 (0.97)	20.50 (0.90)	20.61 (0.98)	0.17
Age at two year weight measurement (m)	24.35 (1.04)	24.44 (1.09)	24.34 (1.03)	0.155
Gestational age (wks)	36.20 (2.48)	35.65 (2.94)	36.29 (2.39)	**<0.001**
Birth weight SDS	-0.54 (0.92)	-0.53 (0.99)	-0.55 (0.92)	0.74

Abbreviations: SD, standard deviation; %, percentage; m, months; wks, weeks, SDS, standard deviation score
[a] p-value for difference between consumers and non-consumers on specified characteristics. Significant differences (p< 0.01) are shown in bold.

5.4.1.2 Descriptive statistics: formula consumption

At the time of diet diary completion (21 months of age), more than 1 in 10 children (13%; *n*= 250) of the analysis sample (*n*= 1897) were still consuming formula milk. Among these children, on average 835 kJ of formula milk was consumed per day (approximately 20% of daily energy intake), but as much as 65% of the total daily energy intake was consumed in formula by some children. On average formula consumers had two formula milks per day but some children had up to five per day, providing as much as 2015 kJ per day **(Table 5.2).**

Table 5.2: Formula consumption descriptive statistics (*n*= 250)

	Mean (SD)	**Range**
Formula variables		
Daily formula frequency	1.9 (0.94)	0.3 – 5.0
Daily energy intake from formula (kJ)	835 (416)	48 - 2015
Energy intake per formula occasion (kJ)	464 (205)	48 - 1840
Daily energy intake from formula (%)	19.8 (10.3)	1.7 – 64.7

Abbreviations: SD, Standard Deviation; kJ, kilojoules; %, percentage

5.4.1.3 The relationship between extended formula milk feeding and i) appetite, ii) food, milk and daily energy intake, and iii) adiposity

Associations between formula consumption and appetitive traits at 16 months of age are shown in **Table 5.3.** Results suggest that extended formula feeding was associated with poorer appetite. Children who were consuming formula at 21 months scored significantly lower than children who were not consuming formula on ‘food responsiveness’ (2.02 and 2.22 respectively) and ‘enjoyment of food’ (3.99 and 4.20). They also scored higher on ‘satiety responsiveness’ (2.89 and 2.65), ‘slowness in eating’ (2.63 and 2.46) and ‘food fussiness’ (2.34 and 2.14); indicating a less avid appetite.

Formula consumers were consuming significantly less cow’s milk than non-consumers (345 vs 1062 kJ respectively, $p < 0.001$) **(Table 5.3)** but nevertheless 82% of formula milk consumers were consuming cow’s milk in addition to formula milk. This implies that formula milk was not simply being used as an alternative to cow’s milk, for example in the case of a cow’s milk allergy. Formula consumers had a significantly higher percentage of daily energy from milks overall than non-consumers (28% vs 25% respectively, *p*= 0.008) but the percentage of daily energy from food was significantly lower (70.4% vs 73.6%, *p*= 0.004). As a result, the total daily energy intake of consumers (4315 kJ) and non-consumers (4373 kJ) did not differ significantly (*p*= 0.31). This suggests that formula was given instead of, rather than in addition to, solid food.

Table 5.3 also demonstrates that at two years of age there was no difference in weight between formula consumers (12.3 kg) and non-consumers (12.3 kg) or weight SDS (0.05 vs 0.06 respectively). Multilevel models also showed that formula group (yes/no) was not associated with weight gain from two to five years (*B*= 5.24; CI= 3.75,20.16; *p*= 0.491).

Table 5.3. Formula consumption[a] by appetitive traits and energy intake variables[b]

	Formula consumers (*n*= 250) (mean (SE))	**Formula non-consumers** (*n*= 1647) (mean (SE))	***t***	***p*-value**[c]
Appetitive traits				
Enjoyment of food (EF)	**3.99** (0.71)	**4.20** (0.59)	-3.51	**<0.001**
Food responsiveness (FR)	**2.02** (0.68)	**2.22** (0.72)	-3.17	**0.002**
Emotional overeating (EO)[d]	1.52 (0.57)	1.62 (0.60)	-1.75	0.085
Slowness in eating (SE)	**2.63** (0.70)	**2.46** (0.62)	2.77	**0.006**
Satiety responsiveness (SR)	**2.89** (0.67)	**2.65** (0.61)	4.21	**<0.001**
Food fussiness (FF)	**2.34** (0.75)	**2.14** (0.68)	3.21	**0.001**
Energy intake variables[e]				
Cow's milk (kJ)	**345** (392)	**1062** (500)	-19.12	**<0.001**
%E from cow's milk	**7.94** (8.73)	**24.10** (11.17)	-19.70	**<0.001**
Total milk (kJ)	1196 (441)	1089 (479)	2.08	0.04
%E from all milks	**28.02** (9.76)	**25.12** (10.49)	2.72	**0.008**
Food intake (kJ)	3050 (709)	3220 (743)	-2.32	0.02
%E from food	**70.36** (9.83)	**73.62** (10.46)	-2.87	**0.004**
Cow's milk & food intake (kJ)	**3396** (792)	**4282** (796)	-12.27	**<0.001**

Total daily energy (kJ)	4315 (731)	4373 (779)	-0.90	0.37
Weight				
Two year weight (kg)[f]	12.30 (1.65)	12.29 (1.41)	0.26	0.792
Two year weight SDS[g]	0.05 (1.15)	0.06 (1.01)	-0.33	0.974

Abbreviations: SE, Standard Error; kJ, kilojoules; SDS, standard deviation score
[a] Formula consumption (yes/no) was the independent variable in all analyses.
[b] Models were each run separately, adjusted for gestational age, birth weight, ethnicity, sex and difference in age between CEBQ and diary completion.
[c] *p*-value for difference between the two groups on listed characteristics. Significantly different mean values ($p< 0.01$) between the groups are in bold.
[d] Modelled using the natural logarithm (ln) of emotional overeating as the original model was not normally distributed. For ease of interpretation the raw means for emotional overeating are presented in the table rather than logarithm transformed scores.
[e] Energy intake was averaged over three days.
[f] Weight at 21m (n= 92) or 27m (n= 140) was used if 24m weight was unavailable.
[g] 321 children (17%) were above healthy weight range (SDS≥1.04).

5.4.1.4 The relationship between appetite and total milk consumption

Table 5.4 shows the associations between appetitive traits at 16 months of age, and total milk consumption (%E from milks) at 21 months of age. Children with poorer appetites were more likely to be consuming greater energy intake in milks than those with more avid appetites. This is reflected in the significant negative associations between two of the three CEBQ 'food approach' scales: 'enjoyment of food' (EF), and 'food responsiveness' (FR), and energy intake from milk. For every one unit increase in EF, children would consume 1.4% less of their energy intake in milk, and for every one unit increase in FR, children would consume almost 2% less of their energy intake in milk. These findings are mirrored in the significant positive associations between 'Satiety Responsiveness' (SR) and energy intake from milks; for every one unit increase in SR, a child would consume 1.7% more energy intake in milk. Interestingly Food Fussiness (FF) was not associated with total energy intake from milks.

Table 5.4. Milk consumption[a] by appetitive traits[b]

	%E from milks (*n*=1897) (*B* (SE *B*))	***p*-value**[c]
Appetitive traits		
Enjoyment of food (EF)	-1.98 (0.55)	**<0.001**
Food responsiveness (FR)	-1.37 (0.46)	**0.003**
Emotional overeating (EO)[d]	-1.05 (0.52)	0.04
Slowness in eating (SE)	0.87 (0.48)	0.07
Satiety responsiveness (SR)	1.73 (0.48)	**<0.001**
Food fussiness (FF)	0.58 (0.50)	0.25

Abbreviations: %E, percentage of daily energy intake; *B*, unstandardized beta coefficient; SE, Standard Error

[a] %E from all milks was the dependent variable in all analyses.

[b] Models were each run separately, adjusted for gestational age, birth weight, ethnicity, sex and difference in age between CEBQ and diary completion.

[c] p-value for significance of B coefficient: associations between total milk consumption and appetitive traits. Significant associations ($p < 0.01$) are in bold.

[d] Modelled using the natural logarithm (ln) of emotional overeating as the original model was not normally distributed.

5.4.2 Qualitative analyses

5.4.2.1 Sample characteristics

Of the 50 families contacted, two parents declined interview via email, and I was unable to make contact with 13 families. This left 35 mothers who agreed to be interviewed and they constitute the sample for the qualitative element of this study. The sample characteristics of these 35 mothers are shown in **Table 5.5**.

Table 5.5. Characteristics of the qualitative analysis sample (mean (SD))

	Qualitative sample (*n*= 35 families; 70 children)
Sex %	
Boys	29
Girls	41
Ethnicity %	
White	60
Non-white	10
Maternal education %	
Low	34
High	36
Age at appetite measurement (m)	15.7 (0.9)
Age at diet diary completion (m)	20.6 (0.7)
Age at two year weight measurement (m)	24.1 (1.3)
Gestational age (wks)	35.7 (2.8)
Birth weight (kg)	2.4 (0.6)

Abbreviations: SD, standard deviation; %, percentage; m, months; wks, weeks; kg, kilograms

5.4.2.2 Themes

Six themes were identified from mothers' explanations of the role of formula milk in the child's diet (**Table 5.6**):

> 1) *Formula milk supplemented the child's diet*: formula milk was offered to compensate for poor appetite and low food intake
> 2) *Concern for child weight*: formula milk was used to enhance growth
> 3) *Soothing*: formula milk was given as part of the night-time routine
> 4) *Recommendations*: formula milk was recommended by health professionals, friends or family
> 5) *Unable to drink cow's milk*: formula milk was given in response to an allergy or dislike of cow's milk
> 6) *Provided beneficial nutrients*: formula milk was perceived to contain nutrients of benefit to the child

The primary reason reported by 60% of mothers for offering formula milk at 21 months of age was that it supplemented the child's diet. Mothers perceived their child to not be consuming enough food, usually because of a poor appetite ("*Because he was a very poor eater. His solid intake was very poor*"). Mothers also referred to using formula because they were concerned about their child's low weight ("*Because the boys were quite small and thin, it was like an added way of getting vitamins and calories*").

Almost half of mothers (46%) referred to the nutrient content of formula as a reason for giving it ("*I kept to formula until they were I think nearly three years old. All the vitamins that were in it and you know it had a lot more of everything so that was my reason*"). A minority (9%) of those interviewed mentioned allergies to cow's milk ("*Because they'd been diagnosed as having a milk and soya intolerance*") or a dislike of cow's milk ("*I think we were a bit late getting them off the formula because they didn't like the taste of real milk*."). Some mothers remembered having been recommended to continue the formula milk, either by friends and family (*n*= 2, 5.7%) or a health professional (*n*= 3, 8.6%) ("*It was with the health visitor's guidance saying that from the age of one they need the milk with the extra iron and that was where she guided me, towards the complete so that was the* *reason we chose that one*."). Others (*n*= 4, 11.4%) were not aware that cow's milk was recommended at that age ("*Well because I was under the impression that in order to have full fat cow's milk they should be two years plus, so we carried on with the formula until that age*").

Almost a third of mothers gave formula in order to soothe their child, usually to help them sleep ("*Possibly with the whole sleeping issues as well I always thought well if they have their formula milk at bedtime they will sleep better. Whether they needed it or not they got it"*).

No mothers mentioned recommendations to cease formula, and gave no indication that they were aware that they were not following the recommendations.

Table 5.6 Mothers' reasons for continuing with formula milk until 21 months of age (*n*= 35)

Reason for continuing with formula milk	*n (%)*
Supplemented diet, e.g. child was not eating much solid food, poor appetite "*We were not convinced that they were getting enough nutrients by eating solid food alone. So that was the main reason*." "*It might have been an element of just making sure they were getting enough calories because they were quite picky eaters."*	**21 (60)**
Concern for child's weight, e.g. formula was used for growth "*We just wanted to keep the milk intake up because we thought it was beneficial for their growth.*" "*It was to build them up, they were always quite small.*"	**10 (29)**
Soothing, e.g. given before bed "*I think it was more or less on a night time, you know not necessarily like a night feed or anything but you know they would sleep so they weren't waking up because they were hungry*." "*I probably thought it would help them sleep better*."	**10 (29)**
Recommendations, e.g. child should not yet have cow's milk "*It was purely that I kept reading that cow's milk wasn't really what you were supposed to give young toddlers, you should stick with formula so I did it with all my kids*."	**9 (26)**
Unable to drink cow's milk, e.g. allergic, disliked *"Because they'd been diagnosed as having a milk and soya intolerance. We could get formula milk on prescription for them and we were slightly concerned to try other things on them because we'd had such a rough ride initially. So we just sort of stuck with it really."* "*It was basically because they didn't like the cow's milk*."	**8 (23)**
Provided nutrients "*Because I wanted to make sure they were getting the nutrients from it. Because I know there are lots of vitamins and stuff in the milk*" "*I thought it was more nutritious to keep them on the formula rather than cow's milk*."	**16 (46)**

5.5 Discussion

5.5.1 Summary of findings

It is widely acknowledged that early diet plays an important role in later eating habits, health and weight. During toddlerhood a transition is made from milk to solid food, and this study sought to explore the role of appetite in this transition. In particular, the role of appetite in extended formula milk feeding among toddlers.

There were three main aims: (i) establish the relationships between a child's appetite, extended formula milk consumption and total milk consumption; (ii) examine food, milk and energy intake patterns and weight gain trajectories for formula milk consumers and non-consumers; and (iii) explore mothers' reasons for continuing with formula milk until at least 21 months of age, using qualitative methods.

It was hypothesised that extended formula-feeding may be directly related to poorer appetites in children and indeed, both qualitative and quantitative methods supported this hypothesis. A standardised measure of appetite (the CEBQ) showed that higher 'food-avoidant' appetitive traits (SE, SR and FF) and lower 'food approach' traits (EF and FR) were both associated with extended formula feeding. Qualitative interviews were used to explore mothers' reasons for continuing with formula milk until 21 months of age and confirmed that poor appetite and low food intake were the most commonly cited reasons for continuation of formula. The majority of mothers said they used formula milk as a supplement to their toddler's diet which may have been lacking energy and nutrients obtained from food sources, often because they were 'picky eaters'. Extended formula milk feeding appears to be, at least partly, a response to the child having a poorer appetite.

Total milk consumption was also found to be associated with key aspects of appetite. Children with more avid appetites consumed less milk than those with poorer appetites. This suggests that children with poorer appetites are more likely to consume milks for longer into toddlerhood.

Formula-consumers had lower intake of cow's milk, but higher intakes from total milks than non-consumers. 206 of the 250 formula consumers (82.4%) also consumed cow's milk, suggesting that formula milk was not simply an alternative to cow's milk and may have had a distinct role in these young children's diets. Formula milk consumers consumed less energy from food than non-consumers and this suggests that parents may have been giving milk to their toddlers intentionally to substitute for the lack of interest in food and subsequent food intake. It is, however, also possible that mothers were inadvertently filling their child up with milk and they were then not hungry or interested in eating food.

The current study found no differences between formula consumers and non-consumers in their total daily energy intake. This lack of difference in the daily energy intake of consumers and non-consumers suggests that formula milk was given to these children instead of food, rather than in addition to it. It is possible that in children with a poor appetite, milk, and specifically formula milk, substitutes for, rather than adds to, solid food intake. Formula feeding may under these circumstances be an effective compensatory method for children with poor appetites to ensure they obtain sufficient daily energy. In line with this, formula consumers and non-consumers did not differ in weight at two years of age, or weight gain between two to five years of age. This suggests that extended formula consumption may not have an enduring impact on weight trajectories. This is in contrast to a previous US study that found that duration of formula feeding (>12 months) was positively associated with weight at 12 and 18 months of age in infants that had been initially breast-fed from birth; but not in those that had been formula-fed from birth (Butte et al. 2000). This is a new field of research and future research should examine associations between extended formula-feeding and later childhood weight. It is also unclear whether there may be longer term impacts of extended milk feeding on eating behaviours, dietary intake and health, so this is worthy of exploration.

In addition to citing poor appetite and food intake as reasons for continuing with formula milk, a quarter of mothers received recommendations from health care professionals to continue with formula. Within the UK the Department of Health (2008) suggest that infant formula, follow-on formula or growing-up milks are not needed once a baby is 12 months old. (Department of Health 2008). This highlights the importance of feeding messages and guidelines being relayed consistently by health professionals. Parents require access to current and correct feeding information.

Some mothers reported using formula milk to soothe their child, often as a means of helping their toddler sleep at night and this suggests that some parents may benefit from advice on alternative ways to soothe their infant at night. This also highlights that parents play a fundamental role in the infant feeding process and parents seem to respond to their child's needs when making feeding decisions

5.5.2 Implications

This is the first study to have explored the role of appetite in extended formula milk consumption and suggests that many children continue to consume high quantities of milk, and specifically formula milks, partly due to a poorer appetite for food. Formula milk appears to act as a substitute for solid food intake, and here, did not result in over-consumption, nor did it appear to result in increased adiposity during early childhood. In fact, it might actually be beneficial for some children who might otherwise fail to thrive. However, it is not clear what other potential implications there might be in terms of future eating habits and health, so further research is needed to explore the long-term impact of extended formula feeding.

5.5.3 Strengths and limitations

This study combined quantitative and qualitative methods to explore the determinants of extended formula feeding. Appetite was measured six months before the dietary measurement, however, the data were not truly prospective. It is not possible to determine whether lower food intake stimulated parents to continue formula feeding, or whether formula milks suppressed appetite and subsequent food intake. It has previously been suggested that milk during toddlerhood suppresses appetite (Wright et al. 2007) and due to the cross-sectional nature of this study this cannot be ruled out. Caution must be taken when concluding that poor appetite drives milk intake and low food intake, and prospective studies need to be conducted to establish causation. Many mothers did report that poor appetite and low food intake were primary reasons for continuing to offer their toddler formula for an extended period of time. However, qualitative interviews were conducted five years after dietary assessment, so mothers may well have forgotten their feeding decisions at the time. It is also possible that parental feeding decisions were made according to health and developmental milestones of the children, rather than solely appetitive characteristics. However, these were not assessed at the time of dietary assessment so conclusions cannot be drawn. Twins have lower birth weight and are born earlier than singletons (Bleker et al. 1979), and formula consumers had lower birth weight and gestational age than non-consumers, so these factors might have played a role in the decision to extend formula milk feeding. The proportion of the Gemini sample (13%) consuming formula at 21 months was higher than that reported in the FITS study (Fox et al. 2004), where only 1.5% of 19-24 month olds were consuming formula. This could partly reflect the twin sample; twin status may promote parental concern about weight and growth, and may not give an accurate picture of prevalence within the general population. Nevertheless, mothers did not cite prematurity or poor growth as main reasons for continuing with formula well into toddlerhood. Also, appetite remained significantly associated with formula consumption after adjustment for birth weight and gestational age.

5.5.4 Conclusions

Both quantitative and qualitative data indicated that maternal feeding decisions during toddlerhood were driven by the child’s relative lack of interest in, and low intake of, solid food, but the possibility of reverse causation cannot be ruled out. Formula milk seemed to be substituting for, rather than adding to, energy from solid foods; and extended formula feeding did not appear to have any enduring impact on weight trajectories. Longer follow-up is needed to determine whether excess milk intake, and specifically formula milk, for toddlers who under-eat has an enduring impact on later weight, or eating behaviours and wider health and development. In order to explore these relationships further, future research could employ standardised measures of parental feeding to explore *how* parents are feeding their toddlers and the role of their child’s appetite in this.

This research has shown that mothers of toddlers with poorer appetites need to be offered more guidance on weaning and introduction of solid food extending beyond 12 months. More research on this topic is needed to ensure parents are given appropriate feeding advice.

CHAPTER 6. APPETITIVE TRAITS AND CONSUMPTION PATTERNS IN EARLY LIFE[l][m]

6.1 Background

Higher food responsiveness, and lower satiety sensitivity are associated with weight gain in early life (van Jaarsveld et al. 2011; Parkinson et al. 2010; Deutekom et al. 2016; Disantis et al. 2011; Gregory et al. 2010a; Mallan et al. 2014; Steinsbekk & Wichstrøm 2015; Steinsbekk et al. 2016; Ling Quah et al. 2015) but what we don't know is *how*. The behavioural aspects of 'everyday' eating that might be associated with these appetitive traits have not been previously explored.

The Behavioural Susceptibility Theory of obesity (Carnell & Wardle 2008) proposes that individuals who are more responsive to external food cues and/or less responsive to internal satiety cues are at increased risk of excessive weight. These traits can be measured using the 'food responsiveness' (FR) and 'satiety responsiveness' (SR) scales of the parent reported CEBQ for children, and BEBQ for infants during the period of exclusive milk-feeding. Studies using the CEBQ and BEBQ have found large variation in SR and FR, even from early infancy before any solid food has been introduced (Wardle et al. 2001; Llewellyn et al. 2011), and both traits have been found to predict infant weight gain from three to 15 months in the Gemini sample (van Jaarsveld et al. 2014). These studies implicate a potential causal role for SR and FR in the development of excessive weight in early life but the behavioural aspects of eating among children with these traits have never been explored. In simple terms, weight gain occurs as a consequence of an individual's energy intake exceeding their energy expenditure. Excess energy might be consumed through a high 'meal frequency' and/or high 'meal size', but the inter-play between these eating patterns, and appetitive traits is unknown.

[l] Data from this chapter has been published in a paper in American Journal of Clinical Nutrition (Syrad, Johnson, et al. 2015)

[m] The peer-review process resulted in changes to this chapter, including the mutual adjustment of meal size and frequency in the analyses and the inclusion of the negative correlation between SR and FR.

On the whole, experimental studies have shown that individuals with lower SR consume more energy when presented with palatable foods (Carnell & Wardle 2007). As mentioned in **Chapter 1**, a validation study of the CEBQ conducted with a British sample of 111 four to five year old children used three behavioural measures of energy intake (energy intake at an ad libitum meal, EAH and energy compensation) to demonstrate that lower SR was associated with higher energy intake during the lunch meal, in the EAH task, and following a preload. It is possible that this might also occur within an everyday context, whereby children with lower SR may consume more food each time they eat (i.e. consume larger meals) than children who are more satiety sensitive. However, no previous study has examined this.

Carnell & Wardle (2007) also demonstrated in their behavioural study that higher FR scores were associated with greater energy intake at the lunch meal. Food cues might therefore increase energy intake at a meal if palatable food continues to be available. However, FR was less strongly associated with energy intake at a meal than SR. While these findings suggest that children with high FR may consume larger meals, there is also reason to believe that FR might in fact be more of an eating onset trait. For individuals with higher FR, food cues elicit a greater urge to eat and may subsequently serve to initiate more eating occasions. Given the high availability and visibility of palatable foods in the current environment, children with higher FR might eat more frequently (higher meal frequency). It is important to explore the relationship between children's appetitive traits and eating patterns in a real-life setting as these behaviours may be very different from those observed experimentally.

Understanding the pathways towards overweight is of clinical importance but to date there has been no research examining whether children's appetitive traits are associated with *how* they eat and drink (how often and how much) within an everyday context (French et al. 2012).

6.2 Study aim

The aim of this study was to explore the relationship between appetitive traits (FR/SR), consumption patterns (size and frequency of eating and drinking occasions), and daily energy intake.

6.3 Methods

6.3.1 Study population

The sample included 2203 children from Gemini. Children without diet diary data or without data on the FR and SR subscales of the CEBQ were excluded, as were children who were missing data on age at diary completion and appetite measurement, maternal education, birth weight and gestational age.

6.3.2 Measures

6.3.2.1 Appetite

Two subscales from the CEBQ-T were used in this study ('Food Responsiveness' (FR) and 'Satiety Responsiveness' (SR)). **Chapter 3** describes the CEBQ-T and each of these subscales in more detail.

6.3.2.2 Dietary intake

The Gemini dietary data was used to classify eating and drinking occasions and daily energy intake (average total kJ intake per day) (described in **Chapter 3).** The size and frequency of eating and drinking occasions ('consumption patterns') were derived and these will be termed 'meal size' and 'meal frequency' for eating occasions, and 'drink size' and 'drink frequency' for drinking occasions within this chapter.

6.3.2.3 Anthropometrics and demographics

Details of data collection for anthropometrics and demographics within Gemini can be found in **Chapter 3**. This study included birth weight, birth weight SDS, two year weight and two year weight SDS. In addition, weight at one year was indexed using weight at 12 months and if this was unavailable, weight at 15 months was used, or nine months if neither 12 months nor 15 months weights were available.

The demographic data included age at data collection (appetite, diet and weight measurement), sex, gestational age, ethnicity (dichotomised into white and non-white) and maternal educational attainment (dichotomised into higher (university level education) and lower (no university education)).

6.3.3 Statistical analyses

Of those children with dietary data (*n*= 2714) 511 were excluded from the primary analyses as they had less than three days of diary entries (*n*= 378), were missing data on the CEBQ (*n*= 118), gestational age (*n*= 25), birth-weight (*n*= 45), or age at CEBQ completion (*n*= 102). Differences in demographic characteristics between the analysis sample (*n*= 2203) and non-responders (*n*= 2601) were examined using chi-square and independent samples t tests. The correlations between FR and SR, and between consumption patterns, were assessed with Pearson's correlation coefficient.

6.3.3.1 Identifying covariates

Covariates included in the analyses were gestational age, birth weight, sex and difference in age at diet-diary completion and appetite measurement. These were associated with appetite and consumption patterns. Maternal education and ethnicity were not associated with either appetite or consumption patterns and were therefore not included in the model. Non-response analyses was conducted to compare the study sample with non-responders.

6.3.3.2 Establishing associations between appetitive traits, consumption patterns and daily energy intake

Relationships between appetite (SR and FR), consumption patterns (size and frequency of both eating and drinking occasions) and daily energy intake were explored using CSGLMs to account for the clustering of twins within families. SPSS version 21.0 program (SPSS Inc.) was used for all analyses. Models were run with each appetitive trait as a continuous, independent variable and each dietary variable as a continuous dependent variable. Models were unadjusted and adjusted for covariates.

To take into account the possibility that consumption patterns might be dependent on prior weight, for example heavier children may consume larger meals or larger drinks as they need more energy, models were also run with additional adjustment for previous growth (weight at 12 months of age). Models were also mutually adjusted for size and frequency to allow assessment of independent associations between appetitive traits and eating and drinking patterns.

6.4 Results

6.4.1 Sample characteristics

Characteristics of the analysis sample (n = 2203) are shown in **Table 6.1**. The mean FR score was 2.22 and the mean SR score was 2.68. Both FR and SR were normally distributed. The average meal size was 753 kJ, and was also normally distributed. The mean weight of the sample at two years of age was 12.3 kg, and weight SDS was 0.07, close to the UK 1990 population mean of 0 (Cole et al. 1995). The majority of children (83%) were classified as healthy weight for their age and sex, with 17% classified as overweight or obese. Compared with non-responders, there was a slight overrepresentation of children who were younger at the CEBQ and diet-diary completion in the analysis sample. There were also more mothers of white ethnicity and who were educated to a higher level and non-responders were slightly more food responsive (p-values <0.001).

Table 6.1. Characteristics of the analysis sample (*n*= 1102 families, *n*= 2203 children)

	Analysis sample (*n*= 2203)	Non-responders (*n*= 2601)	*p*-value
Sex [n (%)]			
Boys	1078 (48.9)	1308 (50.3)	0.35[a]
Girls	1125 (51.1)	1293 (49.7)	
Ethnicity [n (%)]			
White	2104 (95.5)	2362 (90.8)	**<0.001**[a]
Non-white	99 (4.5)	229 (8.8)	
Maternal education [n (%)]			
Low	1105 (50.2)	1687 (64.9)	**<0.001**[a]
High	1098 (49.8)	914 (35.1)	
Age at appetite measurement (m)	15.73 (1.08)	15.95 (1.21)[b]	**<0.001**[c]
Age at diet diary completion (m)	20.65 (1.10)	20.96 (1.35)[d]	**<0.001**[c]
Birth weight SDS [mean (SD)]	-0.55 (0.93)	-0.56 (0.96)[e]	0.65[c]
Gestational age (wks) [mean (SD)]	36.20 (2.46)	36.20 (2.50)[f]	0.98[c]
Meal frequency (times/day) [mean (SD)]	4.95 (1.02)	4.99 (1.20)[d]	0.44[c]
Meal size (kJ) [mean (SD)]	753 (209)	724 (209)[d]	**0.006**[c]
Food Responsiveness (1-5) [mean (SD)]	2.22 (0.73)	2.35 (0.80)[b]	**<0.001**[c]
Satiety Responsiveness (1-5) [mean	2.68 (0.62)	2.69 (0.63)[b]	0.42[c]

Body weight at two years (kg) [mean	12.30 (1.44)	12.35 (1.58)[g]	0.46[c]
Weight SDS at two years [mean (SD)]	0.07 (1.02)	0.07 (1.11)[g]	0.95[c]
Weight status at two years[h] [n (%)]			
Overweight	323 (16.9)	166 (17.4)[i]	0.75[a]
Healthy weight	1588 (83.1)	787 (82.6)[i]	

Abbreviations: %, percentage, m, months; SD, Standard Deviation; wks, weeks; kJ, kilojoules; kg, kilograms; SDS: Standard Deviation Score
[a] Chi-square test for differences between populations. Significant differences (p< 0.01) are shown in bold.
[b] n = 1659
[c] Independent samples t-test for mean differences between populations. Significant differences (p< 0.01) are shown in bold.
[d] n = 511
[e] n = 2436
[f] n = 2581
[g] n = 2581
[h] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (n= 323) or healthy weight (n= 1588) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as weight SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as SDS <1.04.
[i] Total sample of overweight and healthy weight non-responders was n= 953.

6.4.2 Associations between appetitive traits and consumption patterns

6.4.2.1 Appetite and eating patterns

The average meal frequency (average number of eating occasions, excluding water per day) within the sample was five but this ranged from one to 10 eating occasions per day. The average meal size (average kJ per eating occasion, excluding water per day) was 753 kJ but ranged from 247 to 1745 kJ/meal. Meal size and meal frequency were negatively correlated (r= -0.56, p< 0.001) such that the consumption of more energy per eating occasion was moderately associated with eating less frequently throughout the day. There was also a significant negative association between FR and SR, (r= -0.41, p< 0.001), indicating that children who scored lower on SR tended also to score higher on FR.

Associations between each appetitive trait (SR and FR) and meal size and meal frequency are shown in **Table 6.2.** In all models SR was significantly and negatively associated with meal size. A one-unit increase in the SR scale was associated with children consuming 52 kJ less per eating occasion. A child scoring five on the SR scale (most satiety responsive) would consume, on average, 208 kJ less at each eating occasion than a child scoring one (least satiety responsive). Given that children were eating on average five times per day, this could equate to almost 1000 kJ more per day for children with lower (versus higher) SR.

FR on the other hand was not associated with meal size in any model (p-values> 0.2). FR was, however, significantly associated with meal frequency, with more food responsive children eating more often during the day. For a one-unit increase in FR, the change in meal frequency was 0.13, meaning that a child scoring five on the FR scale (most food responsive) would eat approximately 0.5 meals per day more than a child scoring one (least food responsive). Within the sample the average meal size was 753 kJ so this could equate to 376 kJ more per day. Satiety responsiveness was not associated with meal frequency in any model (p-values >0.07).

All associations remained when adjusting for sex, gestational age, birth weight SDS, difference in age between diary completion and CEBQ completion and prior growth. Results also held with mutual adjustment for each meal parameter, providing support for independent effects of SR on meal size and FR on meal frequency.

Table 6.2. Associations between appetitive traits and i) meal size and frequency, ii) drink size and frequency, and iii) daily energy intake (*n*= 2203)

		APPETITIVE TRAITS			
		Satiety Responsiveness		**Food Responsiveness**	
Consumption patterns	**Model**	***B* (SE *B*)**	***p* value[a]**	***B* (SE *B*)**	***p* value[b]**
Meal size (kJ)	1[c]	-51.76 (8.74)	**<0.001**	-2.64 (8.03)	0.74
	2[d]	-47.61 (8.79)	**<0.001**	-6.53 (7.91)	0.41
	3[e,f]	-39.29 (7.57)	**<0.001**	8.49 (6.82)	0.21
Meal frequency (times/day)	1[c]	0.06 (0.04)	0.19	0.13 (0.04)	**0.001**
	2[d]	0.06 (0.04)	0.15	0.13 (0.04)	**0.001**
	3[e,f]	0.15 (0.05)	0.07	0.18 (0.05)	**<0001**
Drink size (kJ)	1[c]	3.59 (7.95)	0.65	-7.07 (7.15)	0.32
	2[d]	4.85 (7.99)	0.55	-7.66 (7.15)	0.29
	3[e,f]	1.38 (9.04)	0.88	-3.22 (8.33)	0.70
Drink frequency (times/day)	1[c]	0.22 (0.05)	**<0.001**	-0.11 (0.04)	**0.005**
	2[d]	0.22 (0.05)	**<0.001**	-0.11 (0.04)	**0.008**
	3[e,f]	0.21 (0.05)	**<0.001**	-0.03 (0.04)	0.44
Daily energy intake (kJ)	1[c]	-109.62 36.07)	**0.002**	36.94 (31.13)	0.24
	2[d]	-75.43 (35.82)	0.04	17.70 (30.71)	0.56

	4[g]	-69.37 (38.16)	0.07	13.43 (31.88)	0.67

Abbreviations: *B*, unstandardized beta coefficient; SE, standard error, kJ, kilojoules
[a] p-value for significance of B coefficient: associations between SR and eating patterns. Significant associations (*p*< 0.01) are shown in bold
[b] p-value for significance of B coefficient: associations between FR and eating patterns. Significant associations (*p*< 0.01) are shown in bold.
[c] Model 1: Complex Samples General Linear Regression Models (CSGLMs) were adjusted for the twin structure of the dataset, unadjusted for covariates.
[d] Model 2: CSGLMs adjusted for the twin structure of the dataset and covariates; sex, gestational age, birth weight, difference in age between diet diary completion and CEBQ completion.
[e] Model 3: CSGLMs adjusted for covariates; sex, gestational age, birth weight SDS, difference in age between diet diary completion and CEBQ completion, and also mutually adjusted for size and frequency to allow assessment of independent associations between appetitive traits and eating and drinking patterns.
[f] Results were unchanged with additional adjustment for prior growth (weight at one year of age).
[g] Model 4: CSGLMs adjusted for covariates; sex, gestational age, birth weight SDS, difference in age between diet diary completion and CEBQ completion, and additionally adjusted for prior growth (weight at one year of age).

6.4.2.2 Appetite and drinking patterns

Associations between each appetitive trait (SR and FR) and drink size and drink frequency are shown in **Table 6.2.** In all models, neither SR nor FR were associated with drink size. SR was, however, significantly and positively associated with the drinking frequency in all models, with more satiety responsive children drinking more often during the day. For a one-unit increase in SR, the change in drink frequency was 0.22, meaning that a child scoring five on the SR scale (most satiety responsive) would drink approximately one more drink per day than a child scoring one (least satiety responsive). Within the sample the average size of a drink was 427 kJ so this could equate to 427 kJ more per day. All associations remained when adjusting for sex, gestational age, birth weight SDS, difference in age between diary completion and CEBQ completion and prior growth. Results also held with mutual adjustment for drink size and drink frequency.

Food responsiveness was negatively associated with drink frequency in the unadjusted model and the model adjusted for covariates, with more food responsive children drinking less frequently during the day. For a one-unit increase in FR, the change in drink frequency was -0.11, meaning that a child scoring five on the FR scale (most food responsive) would drink approximately 0.5 more drinks per day (approximately 214 kJ) than a child scoring one (least food responsive). FR was not, however, associated with drinking frequency in the model mutually adjusted for drink size (p= 0.44) suggesting that the relationship with drinking frequency is not independent of the relationship between drink size and drink frequency.

6.4.3 Associations between appetitive traits and daily energy intake

Associations between each appetitive trait (SR and FR) and daily energy intake are shown in **Table 6.2.** SR was significantly and negatively associated with daily energy intake but when adjustment was made for covariates, and also when prior weight at one year of age was adjusted for, the association disappeared. The adjustment for weight at one year of age might have resulted in null findings because weight is likely to influence an individual's intake; with heavier children consuming more daily energy than lighter children. FR was not significantly associated with daily energy intake in any model.

6.5 Discussion

6.5.1 Summary of findings

This is the first study to explore associations between appetitive traits and young children's consumption patterns in the home context. The primary aim was to explore relationships between appetitive traits (FR/SR), consumption patterns (size and frequency of eating and drinking occasions, and daily energy intake. Findings indicated that SR and FR are characterised by distinct consumption patterns. Children with higher FR ate more frequently than those with lower FR, without any difference in the average size of their eating occasions. On the other hand, children with lower SR consumed more energy during their eating occasions than those with higher SR, without any average difference in their eating frequency. Children with lower SR drank less frequently than those with higher SR. After full adjustment for drink size there was no association between FR and drinking frequency.

There is a plethora of research showing that children with low SR and high FR tend to be heavier (Carnell & Wardle 2008; Mallan et al. 2014; Carnell & Wardle 2009; Webber et al. 2009; Sleddens et al. 2008; Spence et al. 2011; Viana et al. 2008; van Jaarsveld et al. 2014; van Jaarsveld et al. 2011). The findings from this study help us to understand the behavioural expression of these traits. High FR and low SR may be associated with weight gain as a result of specific patterns of eating behaviour (rather than drinking behaviour). Children who are more food responsive eat more often, and children with lower satiety responsiveness eat larger amounts. On the other hand, children with higher food responsiveness and lower satiety responsiveness do not consume smaller or larger drink sizes, but they drink less often. This would appear to somewhat tie into the findings in **Chapter 5** which observed that children with more avid appetites drank less milk but ate more food. Meal size and meal frequency, rather than drink size and drink frequency, might therefore be the potential mechanisms through which children with low SR and/or high FR respectively are at risk of weight gain.

Previous studies have suggested that toddlers and infants self-regulate their energy intake by adjusting their portion sizes depending on the number of eating occasions in a given day (Shea et al. 1992). In a U.S. study of four to 24 month old children, those who ate less often during the day consumed larger than average portion sizes, and children who ate more often during the day consumed smaller than average portions (Fox, Devaney, et al. 2006). In the current study the negative association between meal size and meal frequency suggests that children were regulating their energy intake to some degree; however, it seems that there were individual differences in this self-regulation ability. Children who are highly food responsive do not compensate for more frequent eating by consuming smaller meals, and children who have poor satiety sensitivity do not compensate for larger meal sizes by eating less frequently. Children exhibiting these appetitive characteristics appear to be poorer at energy self-regulation and therefore potentially more susceptible to increased energy intake and weight gain.

One might expect children exhibiting high FR and/or low SR to have a higher daily energy intake as this would help to explain why they gain weight at a faster rate than children with low FR and/or high SR (Carnell & Wardle 2008; Mallan et al. 2014; Carnell & Wardle 2009; Webber et al. 2009; Sleddens et al. 2008; Spence et al. 2011; Viana et al. 2008; van Jaarsveld et al. 2014; van Jaarsveld et al. 2011). In the current study SR was negatively associated with daily energy intake, but not when prior growth was taken into account. There was also no association between FR and daily energy intake, despite the positive associations found between FR and eating frequency. This suggests that in early life children with higher food responsiveness may be compensating just enough for their higher eating frequency by consuming smaller meals such that their increased eating frequency does not translate into a significantly increased total energy intake. This could be due to parents serving smaller portions to children who eat more frequently, and this subsequently reduces meal sizes consumed. Similarly, children with lower SR may be compensating for their larger meal size by eating less often, and therefore the large meals do not lead to a high daily energy intake. Perhaps parents serve larger portions to children who eat less often but this does not result in a higher energy intake.

The minimal associations between both SR and FR and daily energy intake could also potentially be a result of the age of the sample. It is possible that the traits are yet to express themselves fully. Toddlers' eating habits may largely be under their parents' control, with toddlers having very little free choice over how often or how much they eat. The amount consumed at each sitting (meal size) may be more within the child's control, as they are able to either finish everything on the plate, or leave it as they wish. This might be why a small but significant association was observed between SR and daily energy intake in the unadjusted model. The null association between FR and daily energy intake could be because children at a young age who eat more frequently also drink less frequently and the two potentially cancel each other out, thereby regulating total energy intake. Previous research has often focused on children regulating intake by reducing eating frequency in relation to the amount consumed, but potentially some children also regulate intake with *what* they consume (food and drink).

It would be interesting to explore associations between appetite and the patterning of energy intake in a large sample of older children when they have more autonomy over how often and how much they consume. Also, associations between appetite and drinking occasions may be different in older children as drinking patterns may change after toddlerhood when large amounts of milk are no longer consumed.

Despite finding small associations between each of the appetitive traits and daily energy intake, the focus of this thesis is on behavioural aspects of eating; the 'how' of eating. There will, of course, be errors inherent within the diet diaries that mean total daily kJ are not 100% accurate. Estimating portion sizes accurately is very difficult and it is highly likely that intakes reported did not match actual intake. Eating frequency may also be prone to error if parents omit additional snacks during reporting. In so doing this reduces the daily energy intake, and although eating frequency would also be under-reported, it is possible that the eating frequency of children with high FR remains higher than those with lower FR. Indeed, it may be easier to forget (or intentionally omit) an extra snack than to estimate what an appropriate meal size might be, which might help to explain the marginally significant association found between SR and daily energy intake, but null association between FR and daily energy intake. Parents often do not perceive young children as overweight (Jain et al. 2001; Baughcum et al. 2000; Campbell et al. 2006; Syrad et al. 2014) so under-reporting of dietary behaviours is expected to be less likely in a sample of such young children, but the role of under-reporting in specific groups of children i.e. those with high food responsiveness or poor satiety responsiveness is an area for further research in dietary assessment.

6.5.2 Implications

Understanding the behavioural pathways to obesity is crucial for informing targeted interventions to prevent excessive weight gain in children who are behaviourally susceptible to obesity. This study shows that the pathways between appetitive traits - food responsiveness and satiety responsiveness – and the patterning of energy intake are different, and helps to explain why some children are more likely to be overweight than others. Compared to individuals with higher SR and lower FR, children with lower SR consume more energy each time they eat but do not eat more often, whereas individuals with higher FR do not eat more each time they eat, but eat more frequently. Interestingly though, FR was not associated with daily energy intake, and SR was only marginally associated with daily energy intake in an unadjusted model. This is despite consistent literature demonstrating that children with higher FR and lower SR are heavier than those with lower FR and higher SR respectively. This suggests there might be additional mechanisms through which children exhibiting these traits gain weight.

An early study by Birch and colleagues (1987) used a conditioning and extinction experiment in 22 preschool (mean age= 49 months) children to explore the learned control of food intake. Children first ate 100g of a high (607 kJ) or low (251 kJ) yogurt preload, followed 10 minutes later by a 15 minute snack session. Children were placed into either an internal condition whereby they were encouraged to focus on their internal feelings of satiety and hunger, or an external condition where they were to focus on external cues of eating. Only the children in the internal context showed responsiveness to energy density cues; i.e. eating fewer snacks following the high-density preload than the low density preload (Birch et al. 1987). These studies suggest that it is possible to train children to attend to their internal satiety mechanisms, but also possible to train children to become even more food responsive. The former technique could potentially be used to prevent children with lower satiety sensitivity from overeating.

The assessment of appetitive traits in early childhood could identify children with high FR and/or low SR, and their parents could be offered guidance on appropriate eating frequency and portion sizes. The current guidance for parents of toddlers on appropriate meal size and frequency is somewhat limited and some parents might benefit from individualised guidance dependent on their child's appetite.

6.5.3 Strengths and limitations

A validated psychometric measure was used to assess appetite, and eating and drinking patterns were assessed using a reliable method of dietary assessment. Parents were provided with portion guides and asked to report intakes prospectively and not from memory. There were, however, limitations to the study. The cross-sectional nature of the study means that the direction of the relationship is unknown. It may well be that lower SR leads to the consumption of larger meals but it may also be that consuming larger meals, in turn, reduces satiety responsiveness. Prospective research is needed to determine whether meal size in early life can influence a child's SR, or whether SR is the driver of meal size.

The sample consisted of twins and therefore replication of these findings in singletons would strengthen the findings. However, Mallan and colleagues (2014) reported similar mean scores for FR (mean=2.19 vs 2.22) and SR (mean=2.97 vs 2.68) for a sample of two year old singletons (Mallan et al. 2014).

The results of this study cannot be generalized beyond the relatively young age of the sample. It is possible that the relationships between appetitive traits and consumption patterns change as children get older and have more choice over what and how they eat. Future work should explore appetitive traits and consumption patterns at older ages when children have more autonomy with respect to how often and how much they consume. There has been some research into the stability of appetitive characteristics as children get older, for example the continuity in CEBQ scores from four to 11 years of age has been assessed in a sample of British children. The study showed that children who scored relatively highly on food responsiveness at age four also scored relatively highly on the same scale at 11 years of age ($r = 0.44$, $p < 0.001$), and similarly for satiety responsiveness ($r = 0.46$, $p < 0.001$). They also found that children became slightly more ‘appetitive’ as they got older; satiety responsiveness reduced over time, and food responsiveness increased, suggesting an increased likelihood of children overeating as they get older (Ashcroft et al. 2008). This might suggest that similar associations to those found in the current study between appetite and consumption patterns might track over time. However, the tracking of consumption patterns (meal size and frequency) over time has never been explored. It is important to assess this in order to establish whether some children may be at increased risk of future weight gain into later childhood.

The current study is cross-sectional and this does not allow inferences about causation to be made. It seems plausible that appetite would drive specific patterns of eating, but it is also possible that specific appetitive traits might be acquired as a function of how children are fed. For example if a child is continually fed large portions it might interfere with appetite regulation and over-ride satiety cues, rather than the low satiety driving the intake of larger portions.

The current findings may have been different had alternative methods been used to define eating and drinking occasions, and/or meal size and meal frequency. Again, this highlights the need for consistent methods of defining consumption patterns in the literature (Duval & Doucet 2012; Kerver et al. 2006; Oltersdorf et al. 1999).

It could perhaps be argued that the assessment of FR and SR, as well as the assessment of meal size and meal frequency, are not truly independent given that they were assessed by the same people (parents). However, given the definition of meal size in this thesis (kJ per meal or drink), it is unlikely that the assessment of SR was influenced by the assessment of meal size. Visual representations of meals or drinks relate to volume (quantity) but that is not what is measured in this thesis; rather it is the energy content (kJ), which represents the combination of volume and energy density of food or drink eaten. Based on this, it is unlikely that parents would have an accurate idea of the energy content of foods or drinks consumed by their child. Meal or drink frequency may be more salient to parents as it may be easier to remember the number of meals or drinks their child had, compared with estimating the energy content of them. None of the items on the FR subscale mention meal frequency. They ask whether the child is always asking for food ("My child is always asking for food"); if their child was allowed they'd eat too much ("If allowed to my child would eat too much"); if their child had the chance they would eat all the time ("Given the choice my child would eat most of the time", "If given the chance my child would always have food in his/her mouth"); whether the child always finds room to eat more ("Even if my child is full up s/he finds room to eat his/her favourite food"). The items are not directly linked to eating frequency. SR items include asking whether the child gets full before their meal is finished ("My child gets full before his/her meal is finished"), whether the child can eat their meal if they have had a snack beforehand ("My child cannot eat a meal if s/he has had a snack just before"), whether their child gets full up easily ("My child gets full up easily"). Therefore these items do not directly refer to the energy content of the food consumed. Therefore, it can be argued that the assessment of meal size and frequency, and SR and FR, are independent as the CEBQ items refer to broader behaviours, not automatically linked to meal frequency or meal size.

6.5.4 Conclusions

Food Responsiveness and Satiety Responsiveness are traits that each have the potential to tip a child into positive energy balance; high food responsiveness predisposes a child to eat more often, and satiety responsiveness predisposes a child to eat more each time they eat. It is important to identify whether these behavioural aspects of eating are implicated in the development of overweight. This would give insight into potential behavioural pathways through which children with higher food responsiveness and lower satiety sensitivity might gain weight.

CHAPTER 7. CONSUMPTION PATTERNS IN EARLY LIFE AND ADIPOSITY[n][o]

7.1 Background

Chapter 6 highlighted that children with more avid appetites (higher food responsiveness and lower satiety responsiveness) consume more meals, and larger meals, respectively. We know that these appetitive traits place children at greater risk of weight gain and it is possible that by eating too often and/or eating too much, a child will gain excessive weight. However, while the 'patterning' of energy intake (meal size and meal frequency) may play an important role in weight gain, this has been largely unexplored in the literature.

There is now considerable evidence that individuals are consuming food more often, and in larger amounts at each occasion. A cross-sectional U.S. study using data from three nationally representative, population-based surveys examined the contribution of portion size (grams per eating occasion), energy density (kJ/g per eating occasion) and number of eating occasions per day, to changes in daily energy intake from 1977 – 2006 in adults aged >19 years. Increases in portion size and increases in the number of eating occasions were the biggest contributors to increases in daily energy intake (Duffey & Popkin 2011). These increases coincide with increases in childhood obesity at a population level (Ng et al. 2014). However, factors that contribute to trends at a population level cannot be assumed to be the same as those that influence variation at an individual level. Individuals vary in weight, and not all individuals have gained weight in parallel with the environmental changes in recent years. It is therefore important to understand the individual eating behaviours associated with excess weight gain.

Among young children it is widely believed that self-regulation will prevent overconsumption; children will reduce their meal size if they eat frequently,

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[n] Data from this chapter has been published as a paper in Scientific Reports (Syrad, Llewellyn, Johnson, et al. 2016)
[o] The peer review process resulted in changes to this chapter, including the graphs being turned from line graphs to bar graphs, the inclusion of a flow chart of retention rate, and assessment of the risk of overweight based on meal size and frequency.

or will eat less frequently in response to larger meals (Fox, Devaney, et al. 2006). However, in order to explore just how effective this mechanism is, the relative contributions of both meal size and meal frequency to weight gain in early life need to be examined. The evidence summarised in **Chapter 1** highlighted that while there have been a number of cross-sectional studies, and two longitudinal studies, exploring the relationship between weight and meal frequency in children, findings are inconclusive. Some studies suggest an inverse association between meal frequency and higher weight (Barba et al. 2006; Beyerlein et al. 2008; Fábry et al. 1966; Keast et al. 2010; Murakami & Livingstone 2014; Würbach et al. 2009; Bo et al. 2014; Cassimos et al. 2011; Eloranta et al. 2014; Jääskeläinen et al. 2013; Lagiou & Parava 2008; Mota et al. 2008; Neutzling et al. 2003; Preston & Rodriguez-Quintana 2015; Toschke et al. 2005; Vik et al. 2010) while others suggest a positive association exists (Zhang et al. 2009; Farajian et al. 2014). Little research however has been conducted in very young children and therefore findings from previous studies may have been influenced by factors such as older children modifying their intakes in an attempt to lose weight, or under-reporting food intake (Huang et al. 2004).

There have been very few studies exploring associations between meal size and weight in children, and no longitudinal studies have been conducted. Importantly, no longitudinal study to date has examined the relative contributions of *both* meal size (energy consumed) *and* meal frequency in the same sample of young children, over the same recording period. Therefore it has not been possible to determine their relative contribution to excess weight gain or obesity risk during early childhood.

Another factor to consider when exploring the behavioural pathways towards weight gain is the composition of foods consumed. There is increasing evidence that high protein intake for example in early life is associated with higher weight gain (Eloranta et al. 2012; Escribano et al. 2012; Günther et al. 2007), and that a positive association exists between dietary energy density and increased adiposity (Vernarelli et al. 2011). Therefore, although it is important to explore whether individuals who differ in weight status (overweight versus healthy weight) differ in the size and frequency of their eating occasions, to better understand how those factors might be associated with weight status, differences in the composition of meals also need to be explored. For example it could be that overweight children consume more energy during each eating occasion than healthy weight children, but this might be because they consume foods of a higher energy density, rather than foods of a similar energy density but in larger quantities. Only by exploring these factors can interventions be effectively targeted at the key dietary drivers of weight gain in early life.

7.2 Study aim

The primary aim of this chapter is to identify relationships between the patterning of energy intake (meal size and frequency) in early life and weight gain. Longitudinal associations between the size and frequency of eating occasions, drinking occasions and consumption occasions (eating and drinking occasions combined) at 21 months, and weight gain up to age five within the Gemini cohort will be examined.

Three secondary-aims will also be addressed: i) characterise the relationships between the size and frequency of eating and drinking occasions to establish the extent to which children indicate compensatory regulation; ii) examine associations between the size and frequency of eating occasions at 21 months and weight status at two and five years of age to increase understanding of the relationship between eating patterns and clinical weight status; iii) explore relationships between the composition of eating occasions (percentage of energy intake from protein, carbohydrate and fat, and meal energy density) and weight status at two and five years of age.

Lastly, in order to establish the generalisability of the Gemini findings to the general population, a tertiary aim is to replicate the cross-sectional findings from Gemini in a nationally representative sample of UK singletons aged four to 18 months, from the Diet and Nutrition Survey for Infants and Young Children (DNSIYC).

7.3 Methods

7.3.1 Study populations

7.3.1.1 Gemini

Chapter 3 describes participant recruitment within the Gemini study. Children in the current analysis sample were excluded if they did not have three full days of diary entries (*n*= 378), or were missing gestational age (*n*= 4), birth weight (*n*= 41) or weight data at two years of age and at least two additional measurements between two to five years (*n*= 356). This left a sample of 1939 children for analyses; 40% of the baseline Gemini sample (*n*= 4804). **Figure 7.1** shows the flow of participants included in the current analyses. The analysis sample included more mothers of white ethnicity, and they were educated to a higher level than mothers in the rest of the Gemini sample (non-responders; n=2865).

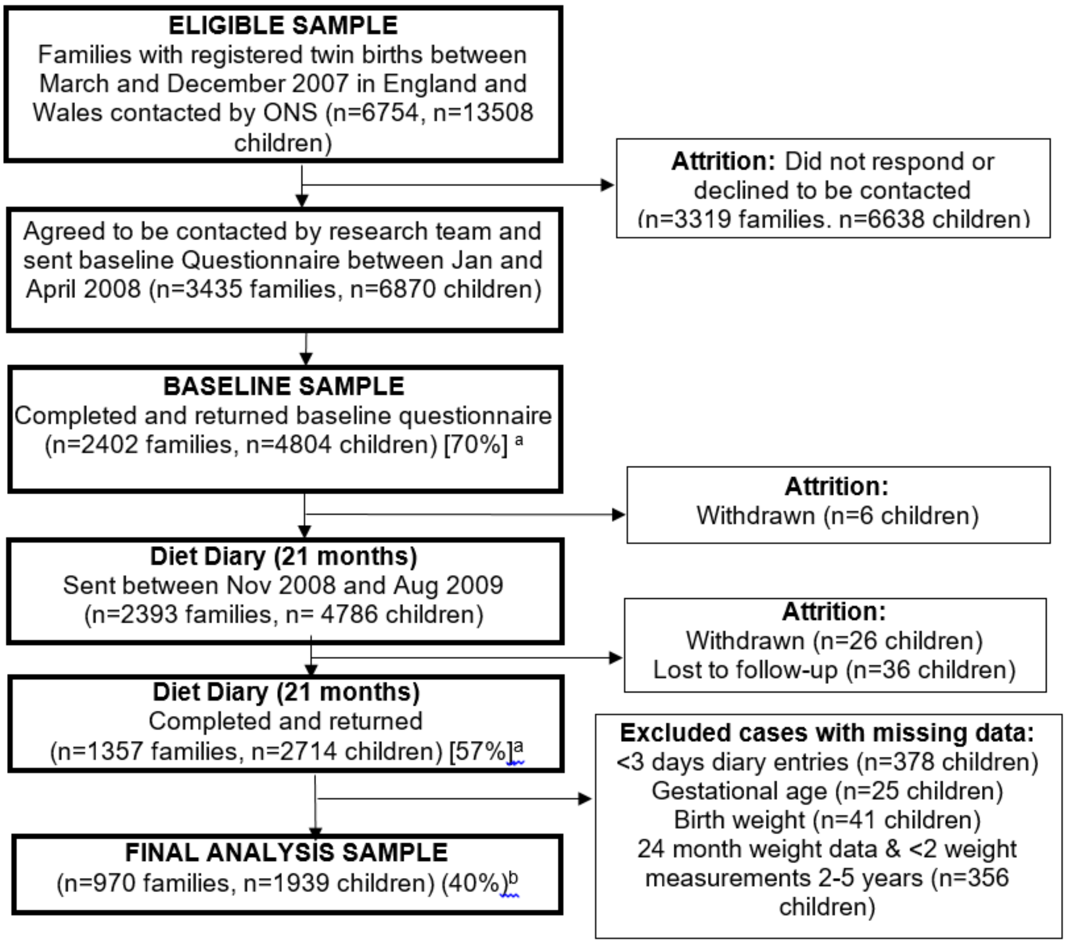

Figure 7.1 Flow chart of participants included in the final analyses
[a] Response rates are given in square brackets [%]
[b] Retention of cohort for current analyses

7.3.1.2 Diet and Nutrition Survey for Infants and Young Children (DNSIYC)

In order to replicate findings from the Gemini twin sample in a sample of nationally representative singletons, dietary data from the Diet and Nutrition Survey for Infants and Young Children (DNSIYC) was utilised. This sample was used for the current study, rather than the National Diet and Nutrition Survey (NDNS), as the DNSIYC sample of four to 18 month olds contains 2,564 children compared to just 386 children aged 18 to 36 months in the NDNS. This larger sample was used to maximise statistical power.

The DNSIYC was a one-off survey conducted in 2011, commissioned by the Department of Health (DH) and Food Standards Agency (FSA) to provide detailed information on the food consumption, nutrient intakes and nutritional status of a nationally representative sample of infants and young children aged four to 18 months living in private households in the UK (Lennox et al. 2013). The survey was carried out by the Medical Research Council Human Nutrition Research (MRC HNR), NatCen Social Research (NatCen), and the MRC Epidemiology Unit and the Human Nutrition Research Centre at Newcastle University. Individuals were randomly selected from Child Benefit (CB) records provided by Her Majesty's Revenue and Customs (HMRC) and stratified by Government Office Region, Index of Multiple Deprivation scores and population density to ensure representativeness of the UK population.

A total of 4,451 individuals were sampled, of which 97% were eligible to take part in the survey. Children with a birth weight less than two kg, those who had used a feeding tube at or after one week of age, no longer lived at the sampled address, had died, or were older than 18 months were ineligible to participate. 2683 (62% of those eligible) completed three (n= 65) or four (n= 2618) day diaries. Within the current study children who were missing weight data (n= 103), and/or weight SDS data (n= 104), and/or birth weight data (n= 2) were excluded. This left a sample of 2564 children from the DNSIYC for the current analysis.

7.3.2 Measures

7.3.2.1 Dietary Intake

Within the Gemini sample, dietary data were collected for 2336 children using three day diet diaries. This process is described in detail in **Chapter 3**. The DNSIYC collected dietary data for children aged four to18 months using three and four day unweighed diet diaries. Parents were provided with details on how to record all food and drinks consumed over consecutive days, including the weekend. Energy and nutrient composition was calculated using the same dietary assessment programme as in Gemini; DINO (Diet In Nutrients Out) (Fitt et al. 2010; Food Standards Agency 2002).

7.3.2.1.1 Consumption patterns

The dietary data within both samples (Gemini and DNSIYC) was manually coded to classify eating and drinking occasions. The methods used to define these have been described in **Chapter 3.** Consumption patterns (meal sizes and frequencies) were derived for each child, averaged over three days. These have been described in **Chapter 3** but in brief the average meal size and frequency of eating occasions, drinking occasions and consumption occasions (eating and drinking occasions combined) were derived. The same variables were computed for the DNSIYC sample.

7.3.2.1.2 Dietary composition

For both samples, each child's daily energy intake was calculated, averaged over the three or four days of data collection. In addition to this, the composition of eating occasions was derived; the average weight (g) and energy density (kJ/g) per eating occasion (with and without drinks included), and the percentage of meal energy (%E) from protein, carbohydrate and fat, for each child. This process is described in more detail in **Chapter 3**.

7.3.2.2 Anthropometrics and demographics

7.3.2.2.1 Gemini

Within Gemini, the baseline questionnaire was the method used to collect demographic information, including: age, gestational age, maternal educational attainment (dichotomised into 'below degree level' [49.5%] and 'degree level or above' [50.5%]), and ethnicity (dichotomised into 'white' [95.8%] and 'non-white' [4.2%]). More details can be found in **Chapter 3**.

Details about the children's weight measurements obtained from parents within Gemini can also be found in **Chapter 3**. In brief, birth weight was reported by parents and birth weight SDS were calculated, which adjust for the sex and gestational age of the child, using British 1990 growth reference data (Cole et al. 1995) with the LMS Growth macro for Microsoft Excel (Cole 2008).

Weight gain (g/week) from two to five years of age was explored using all available weight measurements for each child. Children with less than three weight measurements from two to five years of age were excluded from the multi-level model. The reason for this was because the model fits a straight line to the weight profile over time for each child so excluding children with less than three measurements kept the overall error of estimation small.

Adiposity at two years of age was indexed using weight (kg). Weight SDS at two years was also calculated using the British 1990 growth reference data. Children were classified as 'overweight' or 'healthy weight' at two years of age using weight SDS (≥1.04; at or above the 85th percentile was categorised as 'overweight'). Weight status at five years was indexed using BMI SDS (≥1.04 was categorised as 'overweight'). There were a reduced number of children with five year weight and height measurements (*n*= 1552) due to attrition over time.

7.3.2.2.2 DNSIYC

Parents of children in the DNSIYC took part in a Computer Assisted Personal Interview (CAPI) the day prior to the start of diary completion. These interviews were used to collect background information on the child's sex, age, date of birth, birth weight, ethnicity (dichotomised into 'white' [85.6%] and 'non-white' [14.4%]) and maternal education (dichotomised into 'below degree level' [66.3%] and 'degree level or above' [33.7%]). The child's weight (kg) at diary completion was measured by a trained researcher during a home visit, which took place upon completion of the diet diary. Adiposity was indexed using weight (kg) and weight SDS, using British 1990 growth reference data. Children were classified as 'overweight' if their weight SDS was ≥1.04.

7.3.2.3 Adjusting for misreporting of energy intake

As associations between intake and adiposity were being assessed, it was necessary to address the possibility that parents may have under- or overestimated daily energy intake and this may impact on the associations with weight gain. By excluding children with potentially implausible intakes one might inflate observed associations between energy intake and weight; by excluding thinner children who seemed to eat a lot and fatter children who ate relatively little. Therefore, a secondary analysis was conducted to check that the findings were unchanged after adjustment for under- and over-reporting. 'Plausible' energy intake values for each child were computed using the individualised method (described in detail in **Chapter 3**).

Table 7.1 shows the number of children classified as under-, over- and plausibly reported within the Gemini analysis sample (*n*= 1939) at 21 months. The restricted sample (*n*= 1445) that excluded under- and over-reported values was used in the secondary analysis to determine whether associations between consumption patterns and weight gain may be affected by implausible reporting.

The individualised method for classifying children as under, over or plausibly reported (described in **Chapter 3**) was also used for the DNSIYC sample. The coefficient of variation (CV_t) differed slightly from the Gemini sample as the number of diary days was different (three or four days as opposed to three in Gemini) and the CV_{EI} value (the mean energy intake for each child by the standard deviations for each child) was 4.09% instead of 5.5%. Energy intakes between 80.79% and 119.21% (100% +/- 19.21%) of each child's EER value were considered plausible. Energy intakes below 80.79% of their EER were defined as under-reported and those above 119.21% of their EER defined as over-reported. **Table 7.2** shows the number of children classified as under, over and plausibly reported within the DNSIYC sample. The restricted sample (*n*= 1612) that excluded under- and over-reported values was used in a secondary analysis.

Table 7.1 Frequency of misreported categories (EI/EER) for the Gemini sample

	Under-reported (*n* (%))	**Plausibly reported** (*n* (%))	**Over-reported** (*n* (%))	**Total sample** (*n* (%))
Boys and girls	263 (13.6)	1445 (74.5)	231 (11.9)	1939 (100.0)
Boys only	165 (17.6)	668 (71.0)	107 (11.4)	940 (48.5)
Girls only	98 (9.8)	777 (77.8)	124 (12.4)	999 (51.5)

Abbreviations: EI, energy intake; EER, estimated energy requirements; %, percentage

Table 7.2 Frequency of misreported categories (EI/EER) for the DNSIYC sample

	Under-reported (*n* (%))	**Plausibly reported** (*n* (%))	**Over-reported** (*n* (%))	**Total sample** (*n* (%))
Boys and girls	722 (28.2)	1612 (62.9)	230 (9.0)	2564 (100.0)
Boys only	376 (28.7)	822 (62.8)	111 (8.5)	1309 (51.1)
Girls only	346 (27.6)	790 (62.9)	119 (9.5)	1255 (48.9)

Abbreviations: DNSIYC, Diet and Nutrition Survey for Infants and Young Children; EI, energy intake; EER, estimated energy requirements; %, percentage

7.3.3 Statistical analyses

7.3.3.1 Meal size, meal frequency and weight gain

Multilevel mixed-effects linear regression was used to explore longitudinal associations between consumption patterns (meal size and frequency of consumption occasions, eating occasions and drinking occasions) and weight gain (g/week) from two to five years of age. All weight measurements for the 1939 children are taken account of in the model. Stata version 13 (StataCorp LP 2013) was used to run three-level hierarchical models which accounted for clustering of weight measurements within the child and family. Models regressed weight on age, sex and relevant dietary measures and their interactions with age. The average growth rate within the sample was 36 g/wk; this is the growth rate observed in the sample assuming no contribution from dietary intake. Multi-level models examined the contribution of meal size (per 100 kJ) and meal frequency (per meal) to weekly weight gain (g and % gain), in addition to the mean base growth rate (36 g/wk). Models were run with each meal parameter separately, and also with both meal parameters included to take account of the negative correlations between meal size and meal frequency for consumption occasions (r= -0.68, p< 0.001), eating occasions (r= -0.56, p< 0.001) and drinking occasions (r= -0.13, p< 0.001). This allowed exploration of the independent role of each meal parameter on adiposity when the other was held constant.

Birth weight, sex and gestational age were included as covariates, as well as baseline weight at two years of age to control for differences in subsequent growth rate driven by earlier weight. There was no significant association between maternal BMI and meal size (p=0.21) so this was not included as a covariate. The p-value for all analyses was set at <0.01.

7.3.3.2 Characterising the relationships between meal size and meal frequency

In order to establish the extent to which children indicate compensatory regulation, the relationships between the size and frequency of eating and drinking occasions was characterised using Pearson's correlation coefficients were conducted.

7.3.3.3 Meal size, meal frequency and concurrent weight and weight status

In order to better understand the relationship between consumption patterns and both concurrent weight and clinical weight status, associations between the size and frequency of eating and drinking occasions at 21 months and weight status at two and five years of age were examined.

Two year weight in kilograms, and two year weight SDS were used as continuous dependent variables in separate Complex Samples General Linear Models (CSGLMs). These models accounted for the clustering of twins within families, allowing for both twins to be included. Weight SDS were used in addition to raw weights because the former give an indication of how a child's weight compares to the population mean in 1990, based on the child's exact age at the time of measurement, sex, and gestational age. As previously mentioned, a weight SDS of 0 indicates average weight, a SDS>0 indicates higher weight, and a weight SDS<0 indicates lower weight, compared to the reference population.

Separate models were run with meal size and meal frequency as independent variables. In keeping with the longitudinal models, the models were also run with both meal size and meal frequency in the model to take account of the negative correlations between meal size and meal frequency parameters. These analyses were repeated for the restricted sample with plausibly reported intakes (n= 1445).

Birth weight, sex, gestational age, and difference in age between diet diary completion and weight measurement were included as covariates (because they were potential confounders) in the models. Maternal education and ethnicity were not associated with either weight at two years of age nor with consumption patterns, and were therefore not included in the models. Maternal BMI was correlated with weight at two years of age (r= 0.09, p< 0.001) but it was not correlated with consumption patterns; it was therefore not a true confounder, so it was not included in any of the models.

Univariate Complex Samples General Linear Models (CSGLMs) explored mean differences in meal size and meal frequency by weight status (overweight and healthy weight) at i) two years of age, and ii) five years of age. The odds of overweight at both time points, according to meal size and meal frequency were also estimated using CSGLMs. The method(s) used to classify children as overweight at two and five years of age are described in **Chapter 3**. The analyses were repeated for the sample with plausibly reported intakes only (*n*= 1445). Analyses were adjusted for birth weight, sex, gestational age, and difference in age between diet diary completion and weight measurement.

7.3.3.4 Meal composition and weight status

Univariate CSGLMs also explored mean differences in the composition of eating occasions (meal weight (g), meal energy density (kJ/g), and %E from protein, carbohydrate and fat) and daily energy intake by weight status (overweight and healthy weight) at two and five years of age. Pearson's correlation coefficients also established the relationships between the meal size (kJ) and meal weight (g) of eating occasions, to assess whether eating occasions high in energy intake (kJ) were associated with larger amounts of food (g). This would offer some insight into whether children consuming more energy were consuming different types of meals, or simply larger portions of the same types of meals.

7.3.3.5 Replicating cross-sectional associations in a sample of singletons from the DNSIYC

In order to establish the generalisability of the Gemini findings to the general population, a nationally representative sample of UK singletons aged four to 18 months, from the Diet and Nutrition Survey for Infants and Young Children (DNSIYC) was used to replicate the Gemini findings. The DNSIYC only contained concurrent weights so cross-sectional analyses were conducted. Firstly linear regression models were run, with weight (kg) and weight (SDS) as continuous dependent variables. As with Gemini, separate models were run with meal size and frequency as independent variables, and models were also run with both meal size and meal frequency in the model.

Mean differences in eating occasion parameters (meal size, meal frequency and meal composition) and daily energy intake, by weight status (overweight vs healthy weight) were explored using independent samples t-tests. The odds of a child being overweight based on meal size and meal frequency of eating occasions was explored using Logistic Regression. Pearson's correlation coefficients were also used to establish the relationship between meal size (kJ) and meal weight (g) of eating occasions.

With the exception of gestational age as this was not available in the DNSIYC, all models were adjusted for the same set of covariates as the Gemini analyses; birth weight, age, and sex, as they were associated with child weight and consumption patterns. Maternal BMI, education and ethnicity were not associated with either child weight or consumption patterns so were not included in the models**.**

7.4 Results

7.4.1 Sample characteristics

The characteristics of the Gemini analysis sample (*n*= 1939) are shown in **Table 7.3**. There were equal numbers of girls (51.5%) and boys and most children were of white ethnic background (95.8%). Children were on average 20.6 months (SD=1.0) at diary completion, and 24.4 months at two year weight measurement. The average meal size was 753 kJ, and was also normally distributed. The mean weight of the sample at two years of age was 12.3 kg, and weight SDS was 0.07, close to the UK 1990 population mean of 0 (Cole et al. 1995). The majority (83%) of children at two years of age were a healthy weight for their age and sex, with 17% classified as overweight or obese. Similarly at five years of age a larger proportion of children were healthy weight (91.1%) than overweight, although this was a smaller sample (*n*= 1552).

Compared with non-responders, there was a slight overrepresentation of children who were younger at diet diary completion in the analysis sample, and there were also more mothers of white ethnicity, educated to a higher level (p-values <0.001). There were no differences between responders and non-responders on any other characteristics.

Table 7.3. Characteristics of the analysis sample (*n*= 970 families, *n*= 1939 children)

	Analysis sample (*n*= 1939)	**Non-responders** (*n*= 2865)	***p*-value**
Sex [*n* (%)]			
Boys	940 (48.5)	1446 (50.5)	0.18[a]
Girls	999 (51.5)	1419 (49.5)	
Ethnicity [n (%)]			
White	1858 (95.8)	2604 (90.9)	**<0.001**[a]
Non-white	81 (4.2)	261 (9.1)	
Maternal education [*n* (%)]			
Low	959 (49.5)	1833 (64.0)	**<0.001**[a]
High	980 (50.5)	1032 (36.0)	
Age at diet diary completion (m)	20.6 (1.0)	21.0 (1.5)[b]	**<0.001**[c]
Age at two year weight measurement (m)	24.4 (1.0)	24.4 (1.2)[d]	0.35[c]
Age at five year weight measurement (m)	60.2 (1.8)	60.4 (2.0)[e]	0.13[c]
Birth weight SDS [mean (SD)]	-0.55 (0.92)	-0.56 (0.96)[f]	0.50[c]
Gestational age (wks) [mean (SD)]	36.2 (2.5)	36.20 (2.50)[g]	0.99[c]
Meal frequency (times/day) [mean (SD)]	5.0 (1.0)	5.0 (1.2)[b]	0.46[c]
Meal size (kJ) [mean (SD)]	753 (207)	737 (211)[b]	0.07[c]
Body weight at two years (kg) [mean	12.3 (1.44)	12.3 (1.6)[d]	0.73[c]
Weight SDS at two years [mean (SD)]	0.07 (1.03)	0.06 (1.11)[d]	0.77[c]
Weight status at two years[*n* (%)] [h]			
Overweight	333 (17.2)	156 (16.8)	0.84[a]

Healthy weight	1606 (82.8)	769 (83.2)	
BMI at five years (kg/m²) [mean (SD)]	15.4 (1.3)	15.4 (1.8)[e]	0.92[c]
BMI SDS at five years [mean (SD)]	-0.20 (1.02)	-0.26 (1.28)[e]	0.38[c]
Weight status at five years [*n* (%)] [ij]			
Overweight	138 (8.9)	36 (11.2)	0.54[a]
Healthy weight	1414 (91.1)	316 (89.8)	

Abbreviations: %, percentage, m, months; SD, Standard Deviation; wks, weeks; kJ, kilojoules; SDS: Standard Deviation Score
[a] Chi-square test for differences between populations. Significant differences ($p< 0.01$) are shown in bold.
[b] *n* = 775
[c] Independent samples t-test for mean differences between populations. Significant differences ($p< 0.01$) are shown in bold.
[d] *n* = 935
[e] *n* = 356
[f] *n* = 2700
[g] *n* = 2845
[h] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight or healthy weight relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as weight SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as SDS <1.04.
[i] Weight status at five years of age was derived using BMI standard deviation scores (SDS). Children were classified as overweight or healthy weight relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as weight SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as SDS <1.04.
[j] *n*= 1552 for responders, n= 356 for non-responders

Sample characteristics for the DNSIYC sample are shown in **Table 7.4**. There were slightly more boys (51.1%) than girls and more mothers were from a white ethnic background (85.6%) than non-white. The children were on average 11.1 months old (SD=3.5) at the time of diet diary completion and weight measurement. The prevalence of overweight/obesity in the DNSIYC sample was 33.9% (*n*= 869).

Table 7.4 DNSIYC sample characteristics (*n*= 2564 children)

Characteristic	
Sex	
Boys	1309 (51.1)
Girls	1255 (48.9)
Ethnicity	
White	2196 (85.6)
Non-white	368 (14.4)
Maternal education	
Below degree level	1696 (66.3)
Degree level	868 (33.7)
Age (m)	11.1 (3.5)
Weight at birth (kg)	3.4 (1.1)
Weight at diary completion (kg)	10.0 (1.6)
Weight SDS at diary completion	0.6 (1.0)
Weight status	
Healthy -weight	1695 (66.1)
Overweight/obese	869 (33.9)

Abbreviations: DNSIYC, Diet and Nutrition Survey for Infants and Young Children; %, percentage; SD, standard deviation; m, months; kg, kilograms; SDS, standard deviation score

7.4.2 Meal size, meal frequency and weight gain

Longitudinal associations between consumption patterns at 21 months of age and growth (g/wk) from two to five years of age are shown in **Table 7.5**. In separate models, the size of consumption occasions and eating occasions significantly explained variation in weight gain between children from two to five years of age. For an increase of 100 kJ per consumption occasion, a child's growth rate increased by an additional 4.6 g/week, or 12.8%, above the average growth rate. For a 100 kJ increase in the size of an eating occasion, a child's growth rate increased by an additional 3.5 g/week, or 9.7%, above the average growth rate. The size of drinking occasions was not significantly associated with weight gain (B= 0.69; p= 0.65).

In mutually adjusted models, with meal frequency held constant, the association between meal size and weight gain almost doubled for both consumption occasions (B=8.15; p< 0.001) and eating occasions (B=6.26; p< 0.001). Weight gain increased from 12.8% to 22.6% for every 100kJ increase in the size of consumption occasions, and from 9.7% to 17.4% for every 100kJ increase in the size of eating occasions.

The frequency of consumption occasions (B= 0.07, p= 0.71), eating occasions (B= 0.32, p= 0.20) and drinking occasions (B= -0.17, p= 0.49) were not associated with weight gain. However, in the models that included both meal parameters, higher frequency of consumption occasions (B= 0.67; p= 0.002) and eating occasions (B= 1.04; p= 0.001) were significantly associated with weight gain. This would mean that if the size of the consumption occasion or eating occasion was held constant, each extra consumption occasion would increase a child's growth rate by 0.7 g/week or 1.9% above the average growth rate, and for each eating occasion a child's growth rate would increase by 1 g/week or 2.9% above the average growth rate. Even in mutually adjusted models, however, the frequency of drinking occasions was not associated with growth rate (p= 0.54).

Table 7.5 Consumption patterns and growth from two to five years of age in Gemini (*n*= 1939)[p]

Consumption patterns	Model	Growth rate (g/wk)[a]		
		B **(SE** ***B*****)**	**% growth increase**[b]	**p-value**[c]
Meal size (kJ)[d]				
Consumption occasion	Separate models[e]	4.61 (1.46)	12.8	**0.002**
	Mutual adjustment models[f]	8.15 (1.86)	22.6	**<0.001**
Eating occasion	Separate models[e]	3.47 (1.24)	9.7	**0.005**
	Mutual adjustment models[f]	6.26 (1.48)	17.4	**<0.001**
Drinking occasion	Separate models[e]	0.69 (1.55)	1.9	0.65
	Mutual adjustment models[f]	0.65 (1.55)	1.8	0.68
Meal frequency (times/day)				
Consumption occasion	Separate models[e]	0.07 (0.3)	0.2	0.71
	Mutual adjustment models[f]	0.67 (0.22)	1.9	**0.002**
Eating occasion	Separate models[e]	0.32 (0.25)	0.9	0.20
	Mutual adjustment models[f]	1.04 (0.30)	2.9	**0.001**
Drinking occasion	Separate models[e]	-0.17 (0.24)	-0.5	0.49
	Mutual adjustment models[f]	-0.16 (0.27)	0.4	0.54

Abbreviations: g/wk, grams per week; *B*, unstandardized beta coefficient; SE, standard error; kJ, kilojoules
[a] Analyses have been adjusted for sex, gestational age, birth weight and weight at two years of age as potential confounders.

[p] The multi-level model analyses were conducted by David Boniface, a statistician in UCL's Department of Epidemiology and Public Health

[b] % growth increase in addition to the mean base growth rate (36 g/wk) was calculated by dividing the *B* coefficient by the mean growth rate (36 g/wk) and multiplying by 100.
[c] p-value for interactions between consumption patterns and age. Significant associations (*p*<0.01) are shown in bold.
[d] B coefficient has been re-scaled by multiplying by 100 (per 100 kJ); for example, for each 100 kJ increase in meal size (per consumption occasion) a child's growth rate would increase by 4.6 g/week in addition to the mean base growth rate (36 g/wk).
[e] The separate model for meal size includes the meal size variable only, and the separate models for meal frequency include the meal frequency variable only
[f] The mutual adjustment model includes meal size and meal frequency variables together

7.4.3 Relationships between meal size and meal frequency

Chapter 4 describes the average meal sizes and frequencies for the Gemini sample. The relationships between these were characterised using Pearson's correlation coefficients to establish the extent to which children indicate compensatory regulation.

Table 7.6 shows Pearson correlations between the consumption patterns. Children with a higher daily energy intake had a higher meal frequency; more consumption occasions ($r(1937)=0.20$, $p < 0.001$), more eating occasions ($r(1937)=0.17$, $p < 0.001$) and more drinking occasions ($r(1937)=0.12$, $p < 0.001$). They also had larger meal sizes; they consumed more energy per consumption occasion ($r(1937)=0.52$, $p < 0.001$), eating occasion ($r(1937)=0.54$, $p < 0.001$) and drinking occasion ($r(1937)=0.21$, $p < 0.001$). On the whole, the associations between daily energy intake and all meal size variables were stronger than those between daily energy intake and all meal frequency variables.

There was also a negative association between all meal frequency and meal size variables, suggesting that children who eat or drink more frequently compensate by consuming less energy each time. Children who eat more frequently eat less each time than those eating less frequently ($r(1937)=-0.56$, $p < 0.001$) but this is less true for frequent drinkers; they do consume slightly less energy during each drinking occasion than those drinking less frequently ($r(1937)=-0.06$, $p < 0.001$) but the size of the correlation is very weak. In addition, those eating less frequently tend to consume slightly more energy per drinking occasion, indicated by the small negative correlation ($r(1937)=-0.13$, $p < 0.001$); and vice versa, those drinking less frequently consume more energy per eating occasion ($r(1937)=-0.30$, $p < 0.001$). There was no association between size of eating occasions and the size of drinking occasions ($r(1937)=-0.01$, $p = 0.55$), but children who ate often also drank often ($r(1937)=0.05$, $p < 0.001$).

Table 7.6 Pearson correlation coefficients between the consumption patterns in Gemini (*n*= 1939)

		Meal size			Meal frequency	
	Daily energy intake	Consumption occasions	Eating occasions	Drinking occasions	Consumption occasions	Eating occasions
Meal size						
Consumption occasions[a]	0.52**	-	-	-	-	-
Eating occasions[b]	0.54**	0.92**	-	-	-	-
Drinking occasions[c]	0.21**	0.24**	-0.01	-	-	-
Meal frequency						
Consumption occasions[a]	0.20**	-0.68**	-0.59**	-0.13**	-	-
Eating occasions[b]	0.17**	-0.47**	-0.56**	-0.13**	0.71**	-
Drinking occasions[c]	0.12**	-0.52**	-0.30**	-0.06**	0.73**	0.05**

** Correlation is significant at $p < 0.001$.

[a] A consumption occasion refers to an eating or drinking occasion. Drinking occasions in which water was consumed have been excluded.

[b] An eating occasion refers to an occasion in which food was consumed (and drinks if consumed with food)

[c] A drinking occasion refers to an occasion in which a drink was consumed on its own (without food). Drinking occasions in which water was consumed have been excluded.

7.4.4 Meal size, meal frequency and concurrent weight and weight status

Longitudinal analyses demonstrated a significant association between growth up to age five and the size of eating occasions (**Table 7.5**) but not the size of drinking occasions. Therefore additional analyses for concurrent weight and weight status focused on eating occasions (occasions in which food was consumed, and drinks if consumed with food).

7.4.4.1 Concurrent weight at two years of age

Associations between meal size and frequency at 21 months of age and concurrent weight (at two years of age) are shown in **Table 7.7**. In a separate model, meal size showed a significant, positive association with weight at two years of age (B= 52; p= 0.002). For every additional 100 kJ consumed per eating occasion at 21 months of age, a child weighed 52 g more at two years. Adjusting for meal frequency increased the association between weight and meal size (B= 78; p< 0.001). Results were unchanged using weight SDS as the outcome variable. Similar associations were observed between weight at two years of age and i) the size of consumption occasions (eating and drinking occasions combined), and ii) the size of drinking occasions **(Appendix 7.1)**.

Meal frequency at 21 months of age was not associated with weight at two years when entered on its own in the model (without adjustment for meal size) (B= 0.05; p= 0.89) nor when meal size was added to the model (B= 95; p= 0.02). Results were unchanged using weight SDS as the outcome variable. Similar associations were observed between weight and i) the frequency of consumption occasions (eating and drinking occasions combined), and ii) the frequency of drinking occasions **(Appendix 7.1)**.

Excluding children with implausible intakes from the analyses increased the size of the associations between weight and both meal size and meal frequency. Beta values almost doubled for meal size when children with ‘implausible’ intakes were excluded. The association between meal frequency and both weight and weight SDS also became significant in the mutually adjusted models in the sample with plausibly reported intakes (B= 241; p< 0.001 and B= 0.17; p< 0.001 respectively) **(Appendix 7.2)**.

Table 7.7 Meal size, meal frequency and adiposity at two years of age in Gemini (*n*= 1939)

		Weight (g)[a]		**Weight SDS**[a]	
Eating patterns	**Model**	*B* (SE *B*)	*p*-value[b]	*B* (SE *B*)	*p*-value[c]
Meal size (kJ)[d]					
	Separate models[e]	52 (17)	**0.002**	0.04 (0.01)	**0.002**
	Mutual adjustment models[f]	78 (20)	**<0.001**	0.06 (0.02)	**<0.001**
Meal frequency (times/day)					
	Separate models[e]	0.05 (35)	0.89	0.001 (0.03)	0.97
	Mutual adjustment models[f]	95 (41)	0.02	0.07 (0.03)	0.03

Abbreviations: g, grams; SDS, Standard Deviation Score; *B*, unstandardized beta coefficient; SE, standard error; kJ; kilojoules
[a] Analyses have been adjusted for sex, gestational age, birth weight, difference in age between diet diary completion and weight measurement as potential confounders
[b] p-value for significance of B coefficient: associations between two year weight and consumption patterns
[c] p-value for significance of B coefficient: associations between two year weight SDS and consumption patterns
[d] B coefficient has been re-scaled by multiplying by 100 (per 100 kJ); for each 100 kJ increase in meal size a child's weight at two years would be 52g higher
[e] The separate model for meal size includes the meal size variable only, and the separate models for meal frequency include the meal frequency variable only
[f] The mutual adjustment model includes meal size and meal frequency variables together

7.4.4.2 Weight status at two and five years of age

Associations between the size and frequency of eating occasions at 21 months and weight status (overweight and healthy weight) at two years of age and five years of age are shown in **Table 7.8.**

Children classified as overweight at two years of age consumed significantly more energy during their eating occasions (795 kJ and 744 kJ; $p < 0.001$) but there was no difference in the number of eating occasions (five eating occasions per day, $p = 0.53$). Among the sample of children with plausibly reported intakes, associations were largely unchanged, although the difference in meal size between healthy weight and overweight/obese children rose (from 51 to 90 kJ). A null association between weight status at two years of age and meal frequency was also observed among children with plausibly reported intakes only **(Appendix 7.3)**.

Associations between eating occasion parameters and weight status at five years are also shown in **Table 7.8.** Children classified as overweight at five years of age had consumed larger meals at 21 months than healthy weight children (797 kJ and 746 kJ respectively). Although the mean difference did not reach significance ($p = 0.06$), it was of the same magnitude to that associated with weight status at two years of age (51 kJ); the considerably smaller sample size reduced power to detect statistical significance. Associations were largely unchanged when excluding children with implausible intakes **(Appendix 7.3)** although the difference in meal size increased slightly between the two groups (from 51 kJ to 54 kJ) and this became significant ($p = 0.03$). There was no difference in meal frequency at 21 months between overweight and healthy weight children at five years of age ($p = 0.26$). Mean differences in meal frequency were unchanged when excluding children with implausible intakes.

Table 7.8 Meal size and meal frequency by weight status at two[a] and five[b] years of age in Gemini

Consumption pattern	Full sample			Healthy weight			Overweight			
	Mean (SD)	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value[c]**
Two years of age (*n*= 1939)										
Meal size (kJ)	753 (205)	247	1744	**744 (205)**	247	1744	**795** (205)	322	1452	**<0.001**
Meal frequency	5.0 (1.0)	1.7	9.7	5.0 (1.0)	1.7	9.7	5.0 (1.0)	2.7	8.7	0.53
Five years of age (*n*= 1552)										
Meal size (kJ)	751 (204)	246	1745	746 (199)	279	1745	797 (251)	59	368	0.06
Meal frequency (times per day)	5.0 (1.0)	1.7	9.0	5.0 (1.0)	1.7	9.0	4.8 (1.1)	3.0	8.7	0.26

Abbreviations: SD, standard deviation; SDS, Standard Deviation Score, kJ, kilojoules
[a] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 333) or healthy weight (*n*= 1606) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS ≥1.04 which equates to scores at or above the 85th percentile and healthy weight as weight SDS <1.04; below the 85th percentile.
[b] Weight status at five years of age was derived using BMI standard deviation scores (SDS). Children were classified as overweight (*n*= 138) or healthy weight (*n*= 1414) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a BMI SDS ≥1.04 which equates to scores at or above the 85th percentile and healthy weight as a SDS< 1.04.
[c] Univariate Complex Samples Linear Models (CSGLMs) tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (*p*-value <0.01) are shown in bold.

Figure 7.2 illustrates graphically the average meal size for children classified as overweight compared with those categorised as healthy weight at two years of age. Overweight individuals on average consumed 795 kJ (SD= 204) per eating occasion compared to 744 kJ (SD= 206) for healthy weight children, which equates to an additional 51kJ per eating occasion and an additional 273kJ/day among overweight children. An almost identical pattern was observed among the sample with plausibly reported intakes only (*n*= 1445), although the average difference in meal size between healthy weight and overweight children among the plausible sample (81kJ) was larger than among the full analysis sample (51kJ) **(Appendix 7.4)**.

Figure 7.3 however, shows that healthy weight and overweight children both had five eating occasions per day and the small error bars indicate very little variation among the sample. There were also no differences in meal frequency across healthy weight or overweight in the plausible sample with healthy weight and overweight children eating on average five times per day **(Appendix 7.5)**.

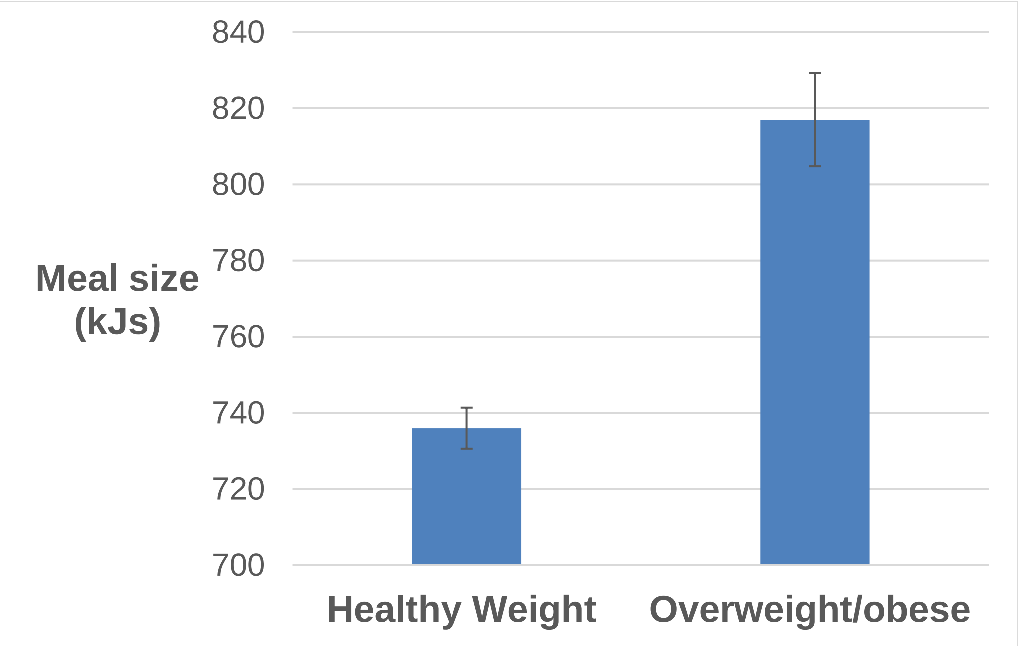

Figure 7.2 Mean scores for meal size (kJ per eating occasion) at 21 months of age partitioned according to weight status at two years of age (*n*= 1939)

Weight status was derived using weight standard deviation scores (SDS). Overweight (*n*= 333) was classified as a weight SDS ≥1.04 (at or above the 85th percentile), and healthy weight (*n*= 1606) as SDS <1.04 (Cole et al. 1995). An eating occasion refers to an occasion in which food was consumed (and drinks if consumed with food).

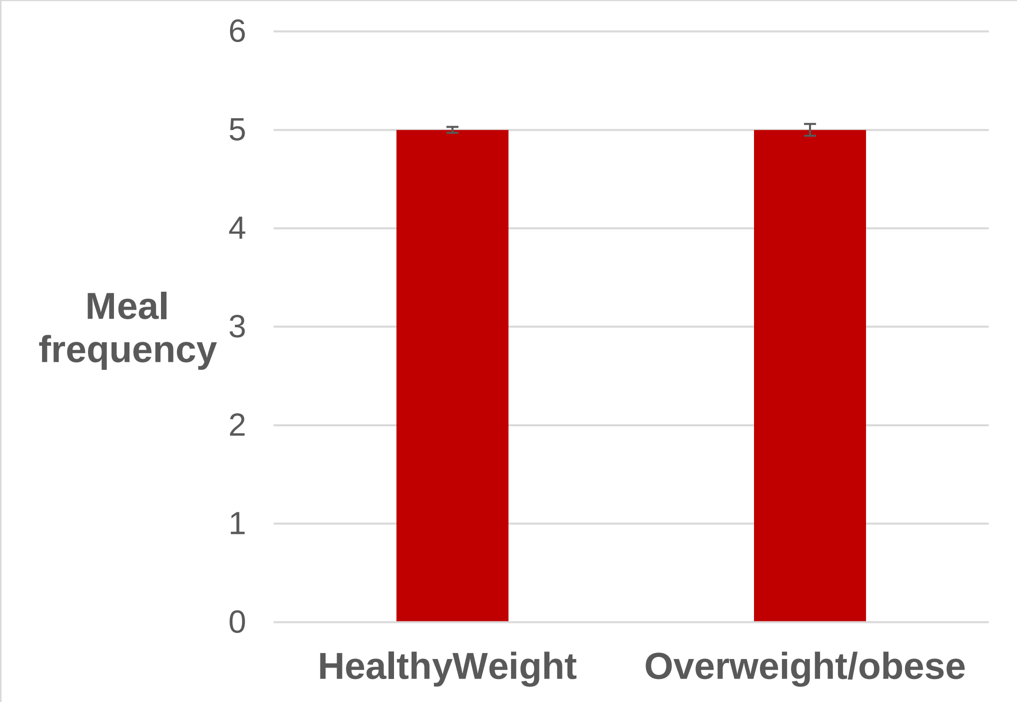

Figure 7.3 Mean scores for meal frequency (number of eating occasions) at 21 months of age partitioned according to weight status at two years of age (*n*= 1939)

Weight status was derived using weight standard deviation scores (SDS). Overweight (*n*= 333) was classified as a weight SDS ≥1.04 (at or above the 85th percentile), and healthy weight (*n*= 1606) as SDS <1.04 (Cole et al. 1995). An eating occasion refers to an occasion in which food was consumed (and drinks if consumed with food).

Table 7.9 shows the odds of a child being overweight at two years of age according to meal size and meal frequency at 21 months of age. Larger meals (kJ) significantly predicted risk of overweight in the model adjusted for covariates (OR 1.10, CI 1.03; 1.18 *p*= 0.006), such that a 100 kJ increase per eating occasion was associated with 10% increased risk of being overweight. With additional adjustment for meal frequency the odds of overweight increased by 4% so with meal frequency held constant, for every 100 kJ increase per eating occasion a child would be at 14% greater odds of being overweight. Associations were similar among the plausible sample **(Appendix 7.6)**, but the odds of being overweight were considerably higher in all models. For example, a 100 kJ increase per eating occasion in the model with adjustment for covariates was associated with 20% increased risk of being overweight and with additional adjustment for meal frequency this rose to 40%. Meal frequency was not significantly associated with risk of overweight at two years (*p*= 0.72), even when adjusting for meal size (*p*= 0.18), but the direction of the effect did become positive (OR 1.13, CI 0.94; 1.36), in line with the continuous associations. In the plausible sample **(Appendix 7.6)**, meal frequency was also not significantly associated with risk of overweight in the unadjusted model; but in a fully adjusted model with mutual adjustment for meal size, increased meal frequency was associated with increased risk of overweight in the plausible sample. Therefore, when meal size is held constant, an additional eating occasion per day was associated with a child being at 13% greater risk of overweight at two years of age (OR 1.13, CI 1.21; 2.00 p <0.001).

Table 7.9 also demonstrates a trend towards an association between larger meal size at 21 months and increased odds of overweight at five years in the full sample. However, associations were non-significant in the unadjusted model (*p*= 0.047), adjusted model (*p*= 0.21) and mutually adjusted model (*p*= 0.51). Meal frequency was also not associated with weight status at five years of age in any model (*p*-values> 0.20). These results held true among the sample of children with ‘plausible’ intakes only (**Appendix 7.7**).

Table 7.9 Odds of being overweight compared to healthy weight at two and five years of age according to meal size and frequency

		Odds of overweight at two years[a]		**Odds of overweight at five years[a]**	
Consumption pattern	**Model**	**OR (95% CI)**	***p*-value[e]**	**OR (95% CI)**	***p*-value[e]**
Meal size	1[b]	1.12 (1.05; 1.19)	**<0.001**	1.12 (1.00;1.26)	0.05
(100 kJ per eating occasion)	2[c]	1.10 (1.03; 1.18)	**0.006**	1.08 (0.96;1.22)	0.21
	3[d]	1.14 (1.05; 1.23)	**0.001**	1.06 (0.90;1.24)	0.51
Meal frequency	1[b]	0.95 (0.82; 1.11)	0.53	0.87 (0.67;1.12)	0.27
(eating occasions per day)	2[c]	0.97 (0.83; 1.14)	0.72	0.85 (0.67;1.09)	0.21
	3[d]	1.13 (0.94; 1.36)	0.18	0.91 (0.66;1.26)	0.58

Abbreviations: OR, Odds Ratio; CI, Confidence Interval; kJ, kilojoules

[a] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 333) or healthy weight (*n*= 1606) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as weight SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as SDS <1.04.

[b] Model 1: Univariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were unadjusted for covariates.

[c] Model 2: Multivariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, gestational age, birth weight, difference between age at diet diary completion and weight measurement.

[d] Model 3: Multivariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, gestational age, birth weight, difference between age at diet diary completion and weight measurement and mutually adjusted for each meal parameter.

[e] Significant associations ($p< 0.01$) are shown in bold.

7.4.5 Meal composition and weight status

7.4.5.1 Weight status at two years of age

Relationships between the composition of eating occasions (percentage of energy intake from protein, carbohydrate and fat, and meal energy density), daily energy intake and weight status (overweight versus healthy weight) at two years of age are shown in **Table 7.10**.

Overweight children had a significantly greater daily energy intake than healthy weight children, as expected given that they ate at a similar frequency but consumed more energy during each occasion **(Table 7.8)**. The difference in the weight (g) of eating occasions was higher in the overweight group than in the healthy weight group (205g and 188g). There was also a significant correlation between the size of eating occasions (kJ) and weight of eating occasions (g) (r= 0.73; p< 0.001) indicating that larger quantities of food were associated with a larger energy content of foods. There were no other differences in meal composition across the two groups (p-values all >0.10). Associations were largely unchanged when excluding children with implausible intakes **(Appendix 7.8)** although the difference in meal weight and daily energy intake increased between the two groups.

Table 7.10 Daily energy intake and meal composition by weight status[a] at two years of age

	Full sample (*n*= 1939)			**Healthy weight** (*n*= 1606)			**Overweight** (*n*= 333)			
Consumption pattern	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Daily energy intake (kJ per day)	4343 (774)	1861	7791	**4293 (761)**	1861	7116	**4569** (782)	2711	7790	**<0.001**
Meal composition										
Meal weight (g)	191 (61)	36	401	**188 (60)**	36	395	**205** (65)	75	401	**<0.001**
Meal energy density (kJ/g)[c]	5.4 (1.7)	2.1	13.4	5.4 (1.7)	2.1	13.4	5.4 (1.7)	2.5	12.5	0.11
Protein per meal (%mE)	11.8 (1.8)	6.2	21.1	11.8 (1.7)	6.1	21.1	11.9 (1.7)	8.0	17.3	0.58
Carbohydrate per meal (%mE)	54.8 (6.1)	26.9	77.8	54.8 (6.1)	26.9	77.8	54.5 (6.0)	41.3	77.3	0.38
Fat per meal (%mE)	33.4 (5.2)	13.3	64.5	33.4 (5.2)	17.4	64.5	33.6(5.0)	13.4	48.9	0.45

Abbreviations: SD, standard deviation; kJ, kilojoules; g, grams; kJ/g, kilojoules per gram; %mE, percentage of meal energy

[a] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 333) or healthy weight (*n*= 1606) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as weight SDS <1.04; below the 85th percentile.

[b] Univariate Complex Samples Linear Models (CSGLMs) tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (p <0.01) are shown in bold.

[c] Results are largely unchanged by calculating energy density of food only (excluding the contribution of drinks to the weight of each meal) (p= 0.84).

7.4.5.2 Weight status at five years of age

Table 7.11 compares the daily energy intake and meal composition by weight status (overweight versus healthy weight) at five years of age. Overweight children had consumed significantly more daily energy at 21 months of age than healthy weight children (4592 and 4309 kJ; *p*= 0.0008). The difference in the weight (g) of eating occasions was higher in the overweight group than healthy weight group (201 g and 188 g), and similar to the size of the difference observed among children at two years of age (205 g and 188 g), but did not reach significance at five years (*p*= 0.08). There were no other differences in meal composition across the two groups (*p*-values all >0.50). Associations were largely unchanged when excluding children with implausible intakes **(Appendix 7.9)** although the size of the differences in meal weight and daily energy intake increased between the two groups.

Table 7.11 Daily energy intake and meal composition by weight status[a] at five years of age

	Full sample (*n*= 1552)			**Healthy weight** (*n*= 1414)			**Overweight** (*n*= 138)			
Consumption pattern	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Daily energy intake (kJ per day)	4334 (750)	2186	7791	**4309 (722)**	2186	7111	**4592 (965)**	2379	7791	**0.008**
Meal composition										
Meal weight (g)	190 (59)	60	401	188 (58)	61	401	201 (66)	60	370	0.08
Meal energy density (kJ/g)[c]	4.1 (0.9)	1.4	8.7	4.1 (0.8)	1.4	8.2	4.1 (1.0)	1.8	8.7	0.94
Protein per meal (%mE)	11.8 (1.8)	6.2	21·1	11.8 (1.8)	6.2	21.1	11.7 (1.9)	8.2	17.3	0.87
Carbohydrate per meal (%mE)	54.7 (6.0)	27.0	77.3	54.7 (6.0)	27.0	77.3	55.2 (6.2)	41.3	70.0	0.60
Fat per meal (%mE)	33.5 (5.1)	13.4	64.5	33.5 (5.1)	13.4	64.5	33.1 (5.5)	19.1	45.7	0.56

Abbreviations: SD, standard deviation; kJ, kilojoules; g, grams; kJ/g, kilojoules per gram; %mE, percentage of meal energy
[a] Weight status at five years of age was derived using BMI standard deviation scores (SDS). Children were classified as overweight (*n*= 138) or healthy weight (*n*= 1414) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a BMI SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as a SDS< 1.04.
[b] Univariate Complex Samples Linear Regression Models (CSGLMs) tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (*p*-value< 0.01) are shown in bold.
[c] Results are largely unchanged by calculating energy density of food only (excluding the contribution of drinks to the weight of each meal) (*p*= 0.78).

7.4.6 Replicating cross-sectional associations in a sample of singletons from the DNSIYC

7.4.6.1 Meal size, meal frequency and concurrent weight

The relationships between meal size, meal frequency and weight among the DNSIYC analysis sample (*n*= 2564) are shown in **Table 7.12**. In line with those observed in Gemini, in the separate model, meal size was significantly and positively associated with weight (*B*= 55; *p*< 0.001). For every additional 100 kJ consumed per eating occasion between four to 18 months of age, a child weighed 55 g more. Adjusting for meal frequency increased the associations between weight and meal size (*B*= 63; *p*< 0.001). Similar associations were found between weight and meal size of i) consumption occasions, and ii) drinking occasions **(Appendix 7.10)**. Associations were largely unchanged using weight SDS as the outcome variable.

In the separate model, weight was not associated with meal frequency (B= 25; *p*= 0.18). The addition of meal size to the model resulted in a significant association between the frequency of eating occasions and weight (B= 53; *p*= 0.006) and the beta value doubled. This indicates that if meal size was held constant then for every additional eating occasion per day a child's weight would be 53 g higher. The significance of this association disappeared when using weight SDS as the outcome variable (*p*= 0.04).

Similar associations to those observed between weight and the frequency of eating occasions were found between weight and frequency of consumption occasions **(Appendix 7.10)**. However, a significant negative association was observed between weight and the frequency of drinking occasions (*B*= -41; *p*= 0.001) such that for every additional drinking occasion, a child's weight was 41 g lower **(Appendix 7.10)**.

After excluding children with 'implausible' intakes, associations increased between weight and all meal size and meal frequency variables. Associations were the same when using weight SDS as the outcome variable, for the sample with 'plausible intakes' **(Appendix 7.11)**.

Table 7.12 Meal size, meal frequency and adiposity in the DNSIYC (*n*= 2564)[a]

		Weight (g)[a]		**Weight SDS**[a]	
Consumption pattern	**Model**	*B* (SE *B*)	p-value[b]	*B* (SE *B*)	p-value[c]
Meal size (kJ)[d]					
	Separate models[e]	55 (11)	**<0.001**	0.05 (0.01)	**<0.001**
	Mutual adjustment model[f]	63 (12)	**<0.001**	0.05 (0.01)	**<0.001**
Meal frequency (times/day)					
	Separate models[e]	25 (19)	0.18	0.01 (0.02)	0.43
	Mutual adjustment model[f]	53 (19)	**0.006**	0.04 (0.02)	0.04

Abbreviations: DNSIYC, Diet and Nutrition Survey for Infants and Young Children; g, grams; SDS, Standard Deviation Score; *B*, unstandardized beta coefficient; SE, standard error; kJ, kilojoules

[a] Analyses have been adjusted sex, birth weight, and age as potential confounders

[b] p-value for significance of B coefficient: associations between weight and consumption patterns. Significant associations ($p< 0.01$) are shown in bold.

[c] p-value for significance of B coefficient: associations between weight SDS and consumption patterns. Significant associations ($p< 0.01$) are shown in bold.

[d] B coefficient has been re-scaled by multiplying by 100 (per 100 kJ); for each 100 kJ increase in meal size a child's weight would be 55g higher

[e] The separate model for meal size includes the meal size variable only, and the separate models for meal frequency include the meal frequency variable only

[f] The mutual adjustment model includes meal size and meal frequency variables together

7.4.6.2 Meal size, meal frequency and weight status

Associations between size and frequency of eating occasions and weight status (overweight and healthy weight) in the DNSIYC are shown in **Table 7.13.** Overweight children consumed significantly more energy during their eating occasions (588 kJ and 541 kJ; p <0.001). Among the sample with 'plausible' intakes only, associations were largely unchanged **(Appendix 7.12)**, although the difference in meal size between healthy weight and overweight children rose (from 47 to 70 kJ) as on average overweight children consumed larger meals in the 'plausible sample' than the full sample (636 kJ compared to 588 kJ). Also, among those with 'plausible' intakes, overweight children ate more frequently than healthy weight children (4.9 versus 4.6 times per day, $p< 0.001$).

Table 7.13 Meal[a] size and meal frequency by weight status[a] in the DNSIYC (*n*= 2564)

	Full sample (*n*= 2564)			**Healthy weight** (*n*= 1695)			**Overweight** (*n*= 869)			
Consumption pattern	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Meal size (kJ)	557 (213)	10	1490	**541 (214)**	10	1490	**588 (209)**	54	1308	**<0.001**
Meal frequency (times per day)	4.5 (1.4)	0.3	10.8	4.5 (1.4)	0.3	10.8	4.6 (1.3)	0.8	10.3	0.36

Abbreviations: SD, standard deviation; kJ, kilojoules
[a] Weight status was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 869) or healthy weight (*n*= 1695) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as weight SDS<1.04; below the 85th percentile.
[b] Independent t-tests tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (*p* <0.01) are shown in bold.

Figure 7.4 graphically represents the average meal size for healthy weight and overweight/obese children in the DNSIYC. Overweight children consumed on average 47 kJ more per eating occasion (235 kJ per day) than those in the healthy weight range. **Figure 7.5** however shows that overweight and healthy weight children ate at a similar frequency (4.6 and 4.5 times per day respectively). This is in line with the Gemini sample, and again, the small error bars indicate very little variation among the sample for meal frequency.

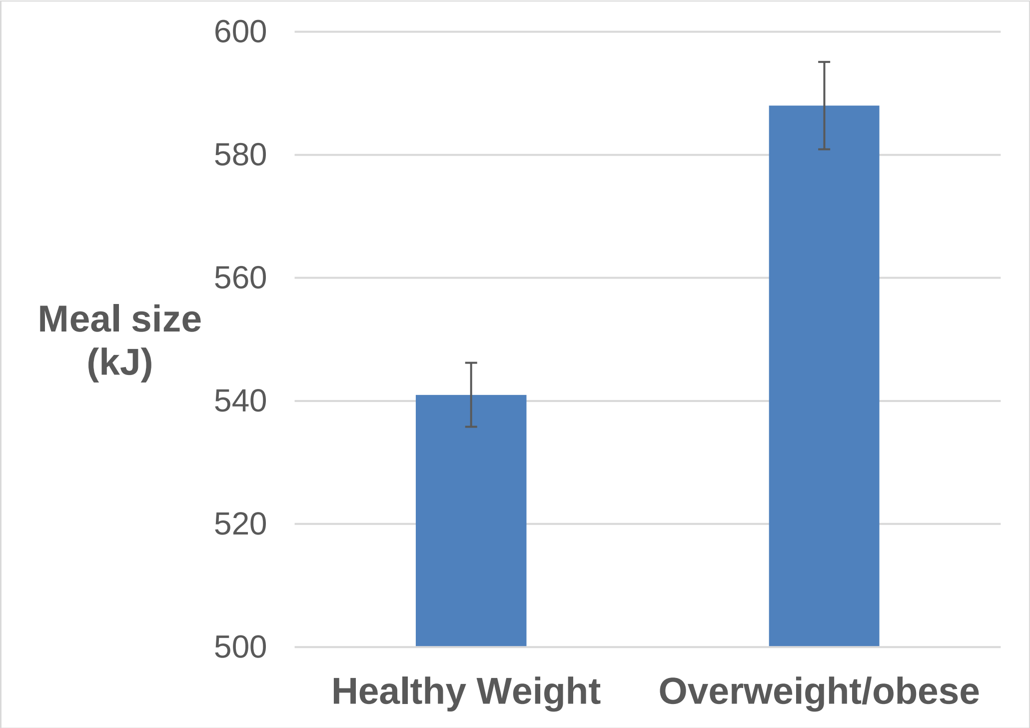

Figure 7.4 Mean scores for meal size (kJ per eating occasion) partitioned according to weight status in the DNSIYC (*n*= 2564)

Weight status was derived using weight standard deviation scores. Overweight (*n*= 869) was classified as a weight SDS≥ 1.04 which equates to scores at or above the 85th percentile (Cole et al. 1995), and healthy weight (*n*= 1695) as a weight SDS< 1.04.

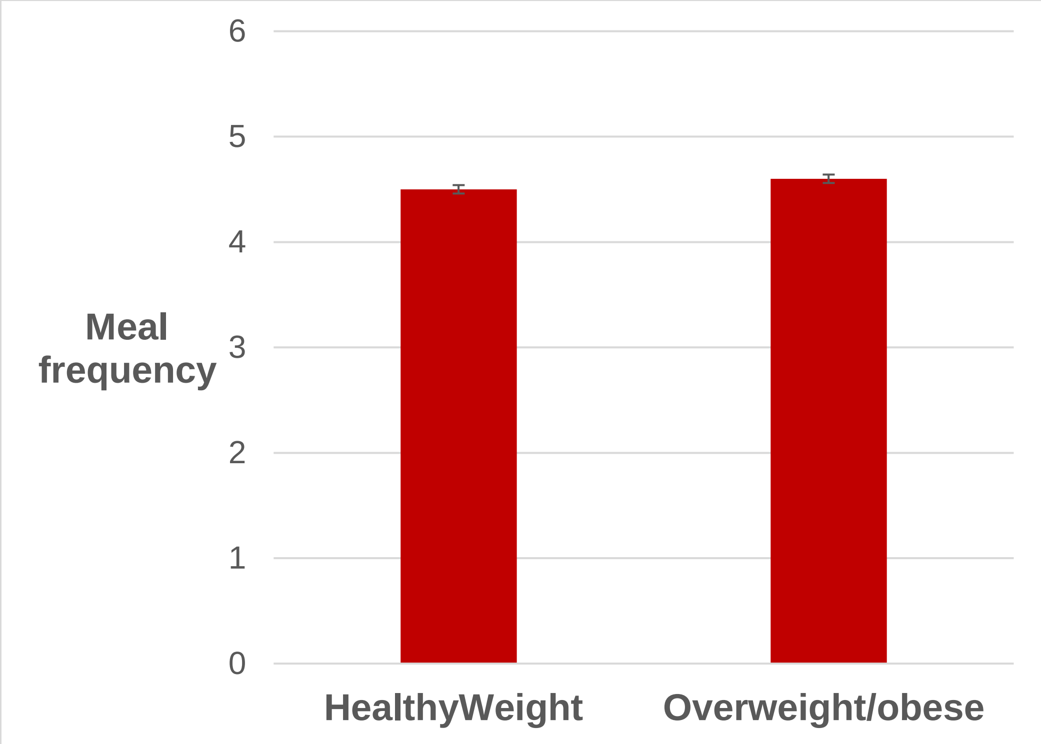

Figure 7.5 Mean scores for meal frequency (number of eating occasions) partitioned according to weight status in the DNSIYC (*n*= 2564)

Weight status was derived using weight standard deviation scores. Overweight (*n*= 869) was classified as a weight SDS ≥1.04 which equates to scores at or above the 85th percentile (Cole et al. 1995), and healthy weight (*n*= 1695) as a weight SDS <1.04.

The odds of being overweight among the full DNSIYC analysis sample are shown in **Table 7.14**. Meal size was significantly associated with increased odds of overweight in all models. In the unadjusted models, every additional 100 kJ per eating occasion increased the odds of being overweight by 11%. In the model adjusted for covariates, every additional 100 kJ per eating occasion increased the odds of being overweight by 8%, and for mutual adjustment with meal frequency, by 9%. Associations were similar among the sample of children with ‘plausible’ intakes only **(Appendix 7.13)** however the odds of overweight were higher in all models for every 100 kJ increase in meal size. In particular, in the model with mutual adjustment for meal frequency, every additional 100 kJ consumed per eating occasion increased the odds of being overweight by 32%.

In an unadjusted model, meal frequency was associated with increased odds of being overweight in the full sample (OR 1.10, CI 1.041; 1.17, *p*= 0.001) but this significance disappeared in both adjusted models. Among the sample with ‘plausible’ intakes, higher meal frequency increased the odds of overweight in a fully adjusted model with adjustment for meal size **(Appendix 7.13)**. This suggests that if meal size were constant, then for every additional eating occasion per day a child would be at 32% greater odds of overweight ($p < 0.001$). This is comparable to the effect size observed for meal size in the fully adjusted model for the sample with ‘plausible’ intakes.

Table 7.14 Odds of being overweight compared to healthy weight according to meal size and meal frequency in the DNSIYC

Consumption pattern	Model	Odds of overweight[a] OR (95% CI)	p-value[e]
Meal size (kJ)	1[b]	1.11 (1.07;1.15)	**<0.001**
	2[c]	1.08 (1.03;1.12)	**0.001**
	3[d]	1.09 (1.04;1.14)	**<0.001**
Meal frequency (times per day)	1[b]	1.10 (1.04;1.17)	**0.001**
	2[c]	1.03 (0.96;1.11)	0.36
	3[d]	1.08 (1.00;1.16)	0.05

Abbreviations: DNSIYC, Diet and Nutrition Survey for Infants and Young Children; OR, Odds Ratio; CI, Confidence Interval; kJ, kilojoules

[a] Weight status was derived using weight standard deviation scores (SDS). Children were classified as overweight (n= 869) or healthy weight (n= 1695) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS≥ 1.04 which equates to scores at or above the 85th percentile, and healthy weight as a SDS< 1.04.

[b] Model 1: Logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were unadjusted for covariates.

[c] Model 2: Logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, birth weight, and age

Model 3: Logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, birth weight, and age and mutually adjusted for each meal parameter.

[e] Significant associations (p< 0.01) are shown in bold.

7.4.6.3 Meal composition and weight status

Table 7.15 shows that overweight children had a greater daily energy intake (3852 kJ and 3566 kJ; $p < 0.001$) than healthy weight children. The weight (g) of eating occasions was also higher in the overweight versus healthy weight group (160 g and 146 g, $p<0.001$), and there was a significant correlation between meal size (kJ) and meal weight (g) ($r= 0.83$; $p< 0.001$). In line with Gemini this indicates that larger quantities of food were associated with a larger energy content of foods. Meal energy density did not differ by weight status ($p= 0.45$) indicating that regardless of whether a child was overweight or healthy weight their eating occasions were of a similar energy density. This suggests that the higher energy content of eating occasions observed among the overweight children was a result of larger portions (g) rather than more energy dense foods. However, the eating occasions of overweight children did also contain a significantly higher percentage of energy from protein (means= 12.4% and 12.0% respectively, $p= 0.005$) and a significantly lower %mE from carbohydrate (means= 57.7% and 58.3% respectively, $p= 0.008$), although the sizes of the differences were very small. The fat content of eating occasions did not differ between the overweight and healthy weight children ($p= 0.24$). There was no significant difference in the frequency of eating occasions between overweight and healthy weight children (4.6 and 4.5 eating occasions per day respectively, $p= 0.36$).

Among the sample of children with plausibly reported intakes, associations were largely unchanged, however the mean difference in energy intake between healthy weight and overweight was larger than among the full sample (414 kJ compared with 286 kJ), as was the difference in meal weight (18 g compared to 14 g) **(Appendix 7.14)**.

Table 7.15 Daily energy intake and meal composition by weight status[a] in the DNSIYC (*n*= 2564)

	Full sample (*n*= 2564)			**Healthy weight** (*n*= 1695)			**Overweight** (*n*= 869)			
Consumption pattern	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Daily energy intake (kJ per day)	3663 (896)	197	7780	**3566 (886)**	197	7780	**3852 (886)**	1106	7518	**<0.001**
Meal composition										
Meal weight (g)	151 (60)	3	420	**146 (60)**	3	382	**160 (61)**	16	420	**<0.001**
Meal energy density (kJ/g)	3.8 (1.0)	0.6	15.3	3.8 (1.0)	0.6	15.3	3.8 (0.9)	1.5	8.5	0.45
Protein per meal (%mE)	12.1 (2.5)	3.2	26.1	**12.0** (2.5)	3.2	26.1	**12.4** (2.5)	4.0	24.5	**0.005**
Carbohydrate per meal (%mE)	58.1 (8.1)	31.7	102.0	**58.3** (8.3)	31.7	100.0	**57.7** (7.6)	34.6	98.4	**0.008**
Fat per meal (%mE)	29.8 (6.7)	2.7	58.2	29.7 (7.0)	2.7	58.2	30.0 (6.2)	2.8	47.6	0.24

Abbreviations: DNSIYC, Diet and Nutrition Survey for Infants and Young Children; SD, standard deviation; kJ, kilojoules; g, grams; kJ/g, kilojoules per gram; %mE, percentage of meal energy

[a] Weight status was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 869) or healthy weight (*n*= 1695) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS≥ 1.04 which equates to scores at or above the 85th percentile, and healthy weight as weight SDS< 1.04; below the 85th percentile.

[b] Independent t-tests tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (*p*-value< 0.01) are shown in bold.

7.5 Discussion

7.5.1 Summary of findings

The aim of this study was to investigate relationships between consumption patterns in early life and adiposity; specifically comparing meal size and meal frequency as predictors of higher weight gain and overweight in young children. There is a paucity of dietary data from young children to explore these associations, and no longitudinal studies have explored the relative importance of both of these meal parameters on weight gain in children. This study has therefore contributed importantly to the existing research base.

This study has demonstrated in a large sample of young children that consuming larger amounts of food rather than eating more frequently in early life predicted weight gain during childhood. Importantly, the longitudinal component to the study has enabled me to determine that heavier children are not simply consuming larger meals because they are heavier and have higher energy needs. Rather, children consuming more energy during each eating occasion and during each consumption occasion at 21 months of age *gained* weight at a faster rate from two to five years of age independent of their baseline weight. Interestingly the energy consumed per drinking occasion was not associated with weight gain. This could be because the types of drinks consumed at 21 months of age are potentially different from those consumed in later childhood. **Chapter 4** identified that at 21 months of age within Gemini, large amounts of milk were consumed. Milk in high quantities would provide a lot of energy but may be quite specific to toddlerhood and therefore may not track during childhood. Food intake and food preferences have previously been found to remain relatively stable during early childhood (Madruga et al. 2012) but drinking patterns, and more specifically, milk consumption may show different associations later in childhood. The tracking of consumption patterns during childhood warrants further research as it has implications for future weight trajectories.

Neither the frequency of consumption occasions, eating occasions or drinking occasions were associated with weight gain. After adjustment for meal size, the frequency of consumption occasions and eating occasions did promote faster weight gain, but frequency of drinking remained un-associated with weight gain. Conceptually having both meal size and meal frequency in the model allows us to see the impact of change in meal size or frequency if all else is equal. However, in the real world, increases in meal size could still be occurring at the same time as reductions in meal frequency and therefore adjustment for each parameter is less ecologically meaningful. Indeed, in this sample of children, changes in meal size were associated with changes in meal frequency, as shown by the negative association between meal size and frequency; children eating more frequently typically ate smaller meals. The estimates from the separate models in the current study therefore reflect the overall effect of both meal size and frequency, in conjunction with one another. In an everyday context this is how changes in meal size might impact on meal frequency. Increased eating frequency *per se* may therefore not increase the risk of obesity if meal size is reduced accordingly. Therefore, whilst the results of the mutually adjusted models are informative, the findings from the separate models in this study are more relevant to public health and demonstrate that meal size but not meal frequency is associated with weight gain in early life. Meal size was associated with weight gain regardless of meal frequency, indicating that meal size is a key target for public health guidance. *How much* energy is consumed each time young children eat appears to influence their weight trajectory, rather than *how often* they are eating.

As discussed in **Chapter One**, there are few recent studies exploring associations between consumed meal sizes in everyday life and adiposity in early life. The only study involving children under three years of age (*n*= 899 children aged one year) found that portion size (g) consumed per eating occasion was positively associated with body weight. However, not only was this cross-sectional in nature which prevents conclusions about causation, but only the weight (g) of eating occasions and not the energy intake (kJ) of eating occasions was assessed. Therefore, while the authors found that the quantity of food consumed was greater in the heavier children than the lighter children, it could not be concluded whether they consumed more energy or simply consumed larger quantities of food of a lower energy density. The current study has built on this by exploring the energy content of eating and drinking occasions and associations with weight gain over time.

The current study found no association between meal frequency and weight gain. This is in contrast to a longitudinal analysis by Ritchie (2012) which concluded that less frequent eating was associated with greater BMI in a sample of 2379 girls aged nine to 10 years at baseline and 19-20 years at follow up (Ritchie 2012). However, the study was conducted in a sample of older children who may skip meals and snacks in an attempt to lose weight or prevent additional weight gain. Another study involving adolescents excluded those who were dieting, and the association between eating frequency and weight disappeared (Summerbell et al. 1996).

No longitudinal study has included meal size as well as meal frequency concurrently in the same sample of children, perhaps because information on meal size is typically lacking from questionnaire-based measures of meal frequency (Kaisari et al. 2013). This makes the findings from the current study unique.

Daily energy intake was positively associated with the size and frequency of consumption occasions, eating occasions and drinking occasions. Children who ate and drank more often, and/or ate or drank larger amounts each time, consumed more energy per day. This is in line with findings from a US study in which the relationship between i) portion size (the mean grams of the quantity of foods consumed per eating occasion), ii) eating occasion frequency (the number of times any food or drink, excluding water, was consumed over 24 hours) and iii) energy intake, in pre-school children aged two to five years was explored. Both portion size and eating frequency were positively associated with energy intake (McConahy et al. 2004). However, a similar study by the same authors involving infants aged 12 to 18 months showed there was a positive association between the portion size of eating occasions and energy intake, but no association between the number of eating occasions and energy intake. This could be explained by the younger age of the sample, as consumption patterns might change during early childhood, especially drinking patterns from infancy to toddlerhood to later childhood. Nevertheless, the consistent association observed in all three studies is between portion size and energy intake, and in the current study meal size was linked to weight gain, but meal frequency was not.

This study has demonstrated that children tend to show compensatory regulation of energy intake as there was a negative association between all meal frequency and meal size variables. Children who eat or drink more frequently tend to compensate by consuming less energy each time. It does seem, however, that this is much more the case with eating occasions than drinking occasions; as the negative correlation was far stronger for eating occasions (-0.56 compared with -0.06). The finding that young children appear to regulate their energy intake to some extent is not new. Previous research has also shown similar associations, with children consuming less each time in response to frequent consumption. Fox et al (2006) explored self-regulation of portion size and eating frequency among a sample of infants in the US aged four to 24 months. They defined the frequency of consumption occasions in the same way as in the current study; the number of times a child had anything to eat or drink during the day, excluding occasions that included only water. They did however compute average portion size z-scores for 45 food groups, rather than exploring the energy intake per consumption occasion as in the current study. The findings demonstrated that children who consumed larger portions, ate less often, and children who consumed smaller portions ate more often. The current study also found this negative association between meal size and frequency, however, it would appear that this regulation is not efficient enough to prevent overconsumption in some children as meal size was associated with weight gain even with meal frequency held constant. The findings from **Chapter 6** suggest that it might be children with poorer SR and/or higher FR that are less able to regulate the size and frequency of their eating occasions.

The current study also showed that children eating less often also drank less often, but they consumed a larger amount of energy in drinks. This would seem to concur with findings from **Chapter 5** in which children with a lower intake of food consumed more milk. However, there was no association between the size of eating occasions and size of drinking occasions. The impact of children consuming large amounts of energy in drinks later into toddlerhood is worthy of further research because it might be that parents are inadvertently filling their child up with milk and subsequently they lose interest in food. This might have implications for later eating habits.

At a cross-sectional level the focus was on eating occasions rather than drinking occasions because eating occasions but not drinking occasions were associated with weight gain over time. Cross-sectional associations between the size and frequency of eating occasions at 21 months and weight at two years of age were in line with the longitudinal findings. Meal size was positively associated with adiposity (weight and weight SDS), but meal frequency was not.

The null association between meal frequency and weight concurs with a previous study in young children which found no association between weight and eating frequency in one to two year-olds (McConahy et al. 2002). It also concurs with a study involving British children aged four to 10 years (*n*= 818) and adolescents aged 11–18 years (*n*= 818). The study demonstrated that regardless of the definition used to define meal frequency: i) any eating episode equal or greater than 15% of total energy intake (other occasions were defined as snacks), and ii) eating episodes occurring at the following times of day; 06.00–10.00, 12.00–15.00 and 18.00–21.00 hours (all other occasions were defined as snacks), there was no association between meal frequency and adiposity (Murakami & Livingstone 2015).

However, the current findings are in contrast to the overall negative association found in a meta-analysis exploring eating frequency and weight associations in children and adolescents (Kaisari et al. 2013). It may be that older children moderate their eating frequency (Woodruff et al. 2008; Boutelle et al. 2009) and under-report their energy consumption (Forrestal, 2011; Lichtman et al., 1992) and weight (Polivy et al. 2013) as a result of their current weight status. This might help to explain previous negative associations between weight and eating frequency in older children. Parent-reports of young children's intake potentially overcome this issue as parents rarely perceive their young children as overweight (Jain et al. 2001; Maynard et al. 2003) and may therefore be less likely to under-report intake. Studies that have explored eating frequency in very young children tend to find no association between weight and eating frequency (McConahy et al. 2002; Huang et al. 2004; Zhang et al. 2009).

To understand more fully the relationship between eating patterns and weight status, the associations between the size and frequency of eating occasions and weight status at two and five years of age were explored. Children who were classified as overweight consumed larger meals than children classified as healthy weight, but they did not eat at a greater frequency. While this was not a significant association at five years of age, the trends were the same and it may simply have been an issue of power due to the reduced sample size.

The difference in meal size (kJ) between the overweight and healthy weight children is small (approximately 50kJ) but children were eating five times per day so it is possible to see how this could accumulate over the course of a day, week, month and lead to excess weight gain. A higher meal size was also associated with increased odds of a child being overweight at two years of age, with and without adjustment for meal frequency. Meal frequency, however, was not associated with increased odds of a child being overweight.

At five years of age there were no significant associations between meal size and odds of overweight. Not only was there a reduced sample at five years of age, but also by categorising children into two groups (overweight and healthy weight) there is even less power to detect statistically significant associations, and this may help to explain the null associations.

Overweight children had a higher daily energy intake than leaner children, and this was not because they had an extra ‘snack’ or ‘meal’ but because they consumed more energy each time they ate. Determining how overweight children were consuming larger amounts of energy during eating occasions is of interest; for example, it could be that they were given more energy dense foods, or simply larger servings of similar foods to those the healthy weight children were consuming. In order to explore this, associations between the composition of meals (percentage of meal energy from protein, carbohydrate and fat, and meal energy density) at 21 months and weight status at two and five years of age were explored.

The findings showed that the proportion of the meal coming from protein, fat, carbohydrate, or energy density, did not differ by weight status at two years of age but meal weight (g) did. This suggests that overweight children consumed more energy during their eating occasions as a result of larger quantities of food, rather than more energy dense foods or foods of a different macronutrient composition. In addition there was a strong positive association between the energy content (kJ) of eating occasions and the weight (g) of eating occasions. This is an important issue in today's current food environment and has implications for intervention. It highlights the importance of parents being given advice on appropriate quantities of food for young children. Feeding advice for parents of young children is often based on the assumption that as long as children are given 'healthy' food, they can be left to choose how much to eat. This stems from research suggesting young children regulate their energy intake by adjusting their portion sizes depending on the number of eating occasions in a given day (Shea et al. 1992; Fox, Reidy, et al. 2006; Fox, Devaney, et al. 2006). Indeed, the current study has demonstrated a negative association between meal size and frequency; but it appears that certain children are more proficient at doing this than others.

At 21 months of age parents largely have control over how often and how much children eat, and therefore the way in which parents are serving larger meals is of interest. It could be that children are served second helpings or simply given larger portions in the first place, and this is worthy of further exploration. Findings would have important implications for parental feeding guidance. During experimental studies, young children have been shown to consume more energy when served larger portions (Fisher, Liu, et al. 2007; Mrdjenovic & Levitsky 2005; Fisher et al. 2003; Fisher, Arreola, et al. 2007; Looney & Raynor 2011; Fisher 2007). A study involving 17 children aged four years demonstrated that when children were served foods differing in energy density (1.8 kJ/g and 5.0 kJ/g) and in two different portion sizes (150g and 300g) it was the portion size which was associated with greater energy intake, and not energy density (Looney & Raynor 2011). This suggests that regardless of energy density, larger portions result in greater consumption. In addition, children's serving sizes appear to be influenced by the servings parents give themselves (Johnson et al. 2014), so if parents serve themselves large amounts of food, they may be more likely to serve their child large portions of food. This highlights the role of parents in children's food intake and the importance of parents' awareness of appropriate portion sizes not only for children but for themselves.

Associations between serving sizes (g) and amounts consumed have also been observed within an everyday context in young children. One study in which 24 hour diaries were completed by parents over five to seven days for 16 children aged four to six years, found that the biggest predictor of the amount of food consumed (assessed by both kJ and grams) was the amount served (Mrdjenovic & Levitsky 2005). This naturalistic study indicates that larger serving sizes can over-ride the energy regulation mechanisms that young children are assumed to have. A recent survey of 1000 parents in the UK, conducted by the Infant and Toddler Forum, found that 79% of parents offered bigger portions than recommended when serving meals, drinks and treats. 73% of parents were concerned that their child was not eating enough (The Infant and Toddler Forum 2016). Offering 'healthy food' in large quantities may still be a risk factor for overweight for some children and it cannot be assumed that children are able to perfectly regulate their intake so parents need to be aware of their children's energy needs and how much is too much.

The cross-sectional findings from Gemini were replicated in the DNSIYC sample of younger children aged four to 18 months. Meal size was positively associated with weight and weight SDS but meal frequency was not. Also in line with the Gemini findings is that within the DNSIYC, the size of eating occasions was larger in overweight children than healthy weight children, but there was no difference in meal frequency by weight status. Also, larger meal size increased the odds of being overweight compared to healthy weight. Interestingly, increased meal frequency also increased the odds of being overweight among the DNSIYC sample but this was in the unadjusted model. In adjusted models there was a null association between meal frequency and the odds of overweight. Interestingly, among the

DNSIYC sample with plausible intakes, overweight children ate more often than healthy weight children. This might suggest that parents of children with implausible intakes may have under-reported their eating frequency, resulting in no difference between overweight and healthy weight children in their meal frequency. More research is needed into *how* parents under and over-report energy intake; whether it is by omitting an extra snack (thereby reducing meal frequency) or by reporting smaller portions (thereby reducing meal size).

Overweight children in the DNSIYC had higher daily energy intakes than healthy weight children and similar to Gemini, this was due to their larger meal sizes, rather than their frequency of eating. However, while the meal weight (g) was larger in the overweight children than the healthy weight children and suggests that they were consuming larger portions, and there were no differences in the energy density of eating occasions, there were subtle differences in the composition of their eating occasions. Overweight children consumed a greater percentage of energy from protein, and less energy from carbohydrate. This may be in part due to the age of the sample, and the fact that a larger proportion of energy was consumed as drinks in this group. A previous study in Gemini found that protein intake was associated with higher weight gain (Pimpin et al. 2016) and another Gemini analysis found that a large proportion of protein was consumed in dairy products, and predominantly milks (Pimpin et al. 2015). These observations may be useful in explaining the findings observed in the DNSIYC in which heavier children consumed meals with greater protein content. It could be that heavier children were consuming greater quantities of milk. While this does not concur with the findings described in **Chapter 5** in which Gemini children who were consuming formula milk consumed more milk than those not consuming formula, but were not heavier, the Gemini children were older and milk was playing less of a role generally in their diets. In DNSIYC the children were younger and milk would have constituted a predominant part of their diet.

7.5.2 Implications

This study highlights the role of consumption patterns in excess weight gain during early childhood. Meal size rather than meal frequency predicted weight gain, independent of earlier weight. While differences in meal size between healthy weight and overweight children are small, over time there is the potential for dramatic influences on weight trajectories. Cross-sectional associations between adiposity and meal size were observed in two independent samples of young children, and indicate that dietary intake, and specifically meal size, in children as young as four months of age may be influencing weight in early life.

The main implication of these findings is the importance of appropriate portion sizes for young children. It has been suggested that at a population level, large portion sizes result in energy over-consumption and may be a contributing factor to the current obesity epidemic (Ledikwe et al. 2005; Young & Nestle 2002). Recently it has been proposed that one way of combating this would be to introduce policies to limit portion sizes, for example reducing portion sizes in restaurants, reducing the size of tableware (Marteau et al. 2015) or capping the serving sizes of sugar sweetened beverages. However, whilst these changes may help with tackling obesity at a population level, the current study highlights individual differences in consumption behaviour which lead to weight gain. Not all children consumed large meal sizes and not all children gained weight at the same rate. It is therefore possible that some children are more susceptible to overeating in response to larger serving sizes and this has implications for intervention. For example, a relatively consistent body of literature demonstrates that heavier children have lower satiety responsiveness than their leaner counterparts (Webber et al. 2009; Jansen et al. 2003; Carnell & Wardle 2008; Carnell & Wardle 2009; van Jaarsveld et al. 2011) and it is possible that these children are more susceptible to larger portions. Parents and carers of certain children may need to guard against 'over-serving' and may need to be offered more guidance on appropriate portion sizes. In addition, the provision of information on the nutritional composition of foods and drinks and recommended energy intakes for young children may be warranted.

Until recently there has been very little guidance on portion size for young children. The Infant and Toddler Forum has now developed a factsheet providing evidence-based portion size ranges for a variety of foods for children aged one to four years (More 2012). However, this guidance is for a relatively wide age range, and as a result a range of portion sizes are provided and parents are advised to 'feed to the child's appetite'. Some parents may have a child who is potentially more susceptible to weight gain through the consumption of larger portions, as demonstrated in **Chapter 6**, and may benefit from more tailored guidance. Other strategies which may help limit meal size are to avoid offering second helpings or offering dessert, and avoiding incentives for 'plate clearing' as this might over-ride satiety mechanisms. Currently there is little guidance to parents on appropriate serving sizes for young children and an analysis of policies to promote healthy portion sizes in the US found this to be a neglected area (Pomeranz & Miller 2015). More research needs to be conducted to identify appropriate interventions for helping parents feed their children in a way that fosters healthier growth patterns. More advice on feeding practices, especially on meal size, may help prevent excess weight gain.

7.5.3 Strengths and limitations

This study has several strengths, but also some limitations. The longitudinal nature of the study, with prior weight at two years of age adjusted for, offers more confidence that meal size is a driver of excessive weight gain. Increases in growth were not a result of earlier weight but more likely a result of dietary intake, specifically higher meal size.

The data from this study were from the largest dietary dataset for toddlers in the UK and the findings were also replicated in another large sample of younger singletons. The young age of both samples is a strength for a few reasons. In terms of the reliability of the dietary data used in the study, very young children are unlikely to be modifying their diet as a result of current weight status such as skipping meals to lose weight (Woodruff et al. 2008; Boutelle et al. 2009). Parents often do not perceive young children as overweight (Jain et al. 2001; Baughcum et al. 2000; Campbell et al. 2006) so under-reporting of dietary behaviours was also expected to be less likely in a sample of such young children. Over-reporting has been found to be an issue in younger children (Huang et al. 2004) but we duplicated the findings in the sample with 'plausible' intakes in both Gemini and the DNSIYC and were able to conclude that issues of under or over-reporting made very little difference to the results and conclusions drawn.

Parents in both samples were provided with portion guides and detailed instructions on recording food and drink intake which would help with standardisation and potentially reduce errors. Also, in the DNSIYC, in order to minimise error in dietary intake reporting, researchers visited families at home to review the diary entries and identify any ambiguities. There were, however, differences in the sample. For example in the DNSIYC, children with a birth weight of less than two kg or those who had used a feeding tube at or after one week of age were excluded from analyses. In Gemini, due to the twin nature of the sample and increased incidence of prematurity, there would have been children in the sample that weighed less than two kg or used a feeding tube after one week of age.

Health professional measured weights were used for the first two years in the Gemini study, and were reported by parents from two years onwards. Parent-reports of weight could introduce error but all parents were supplied with weighing scales and height charts to ensure standardisation. The correlation between researcher-measured and parent-measured weight has been shown to be high (r= 0.83) in another study of British twin children (Wardle et al. 2008). Parental under-reporting of weight for overweight children also increases with age (Maynard et al. 2003; Akinbami & Ogden 2009; O'Connor & Gugenheim 2011) so it is likely to be less of a problem in the current study as the children were young. In addition, the Gemini findings were replicated in the DNSIYC and children's weights in that sample were researcher measured.

There were limitations to the study. Information on energy expenditure was not collected in either Gemini or the DNSIYC so it was not possible to determine the independent contribution of energy intake on growth. Nevertheless, children consuming larger meals were heavier and gained more weight, suggesting that these children were not in energy balance.

The study described here used a number of meal size and meal frequency variables which were defined according to whether food or drink was consumed. This avoided subjective judgements based on timing or content which could be unreliable for children of this age and there were relatively consistent findings regardless of the definition used. However, there is currently no standard definition of an eating or drinking occasion (Gatenby 1997; Duval & Doucet 2012; Oltersdorf et al. 1999; Kerver et al. 2006) and it is possible that if other definitions had been used, results may have differed (e.g. parent-defined meals or snacks, or the energy content of each eating occasion). This simply highlights the need for consistent methods of eating occasion definitions in the literature (Duval & Doucet 2012; Oltersdorf et al. 1999; Kerver et al. 2006). An eating occasion included drinks consumed at the same time as food, which might have affected the energy density of the meal. However, meal energy density was not associated with weight status, either with or without drinks included suggesting the definition of a meal for this sub-section of the analysis was unaffected by the inclusion of drinks.

The method used for dietary data collection is open to error as accuracy is dependent on the parents' recollection of the food and drinks consumed by their children. In order to try and overcome this parents were asked to complete the diaries prospectively and not from memory. Diet diaries were completed in great detail, with families providing comprehensive energy and nutrient data which cannot be obtained through food frequency questionnaires (Bingham, Gill & Welch, 1994).

Diet diaries are time-consuming so it was likely that the families most invested in the Gemini study, or those with the least competing daily challenges, completed them. The majority of the Gemini sample also consisted of highly educated mothers and it could be that these parents have greater knowledge of dietary recommendations resulting in the reporting of more favourable dietary intakes (Macdiarmid & Blundell 1998). However, the DNSIYC was a less well-educated sample and the findings were replicated, suggesting education may not have been an important factor.

There was a reduced sample of children with weight data available at five years of age in Gemini, as parental compliance with returning measurements reduced over time. Attrition is unfortunately a common problem among cohort studies. Nevertheless I have been able to demonstrate that the differences in meal size at 21 months according to weight status at two years and at five years were of a similar magnitude, despite the differences not reaching significance at five years of age. The results from the mixed-models analyses focused on weight gain from two to five years of age, rather than point estimates of overweight, and this is a benefit of the model. The model took advantage of all available weight data, with an average of six weight measurements per child from two to five years of age, and children with less than three measurements were excluded from analyses. However, the fitted model was likely to be biased towards earlier weights given the reduced compliance to providing measurements over time. Nevertheless, associations were essentially unchanged after adjusting for weight at two years of age.

As with other cohort studies, selection bias may have been introduced; the analysis sample consisted of 40% of the initial baseline sample. This brings into question how generalizable the sample was, as does the twin nature of the sample in terms of how applicable the findings are to singletons. However, not only did **Chapter 4** demonstrate that the diets of children in Gemini been found to be comparable to those recorded in a nationally representative sample (the National Diet and Nutrition Survey), but also in the current study findings were replicated in the large sample of singletons from the DNSIYC. As expected, meal sizes were smaller in the DNSIYC as the children were younger than in Gemini (four to 18 months compared to 21 months), but the difference in average meal size between the overweight and healthy weight children in both samples was the same; approximately 50kJ. This suggests that the Gemini findings are not specific to twins, and that these associations between meal parameters and adiposity occur at an even younger age. This has important implications for targeting early life nutrition and obesity in early life but also shows that Gemini is a valuable resource for exploring dietary influences on weight trajectories.

A large proportion of this study was cross-sectional in nature, and in particular, the replication using the DNSIYC data does not enable conclusions to be drawn about the impact of meal size on weight gain in singletons. The age range of the DNSIYC sample was wide (14 months) and intuitively one might expect older children to be heavier and have higher energy needs, hence a higher meal size. However, associations remained when weight SDS was used as a continuous variable and used to categorise children as overweight or healthy weight.

7.5.4 Conclusions

In conclusion, this study is the first to explore the relative contribution of meal size and meal frequency to weight gain during early childhood. Larger meals, but not more frequent eating, were associated with greater weight gain among young children. It is important that parents are provided with support and guidance to develop appropriate feeding behaviours, especially to avoid over-serving in early life. Parents need to be made aware that weight tracks into later life, and that *how much* children eat, and not just *what* they eat when they are very young is likely to impact on their future weight. There is a need for further research into how children are fed larger meals and how parental feeding practices and child consumption patterns may influence one another. In addition, given the findings from **Chapter 6** in which children with lower satiety responsiveness consumed larger meals, there is a need to examine whether meal size might be the dietary mechanism through which these children gain weight.

CHAPTER 8. MEAL SIZE AS A MEDIATOR OF THE ASSOCIATION BETWEEN SATIETY RESPONSIVENESS AND ADIPOSITY

8.1 Background

Extensive literature indicates that children with lower responsiveness to satiety are more susceptible to weight gain (van Jaarsveld et al. 2011; Parkinson et al. 2010; Deutekom et al. 2016; Disantis et al. 2011; Gregory et al. 2010a; Mallan et al. 2014; Steinsbekk & Wichstrøm 2015; Steinsbekk et al. 2016). **Chapter 6** demonstrated that, within an everyday context, children with lower satiety responsiveness consumed larger meals, and **Chapter 7** demonstrated that larger meals drive weight gain in early childhood. This suggests that meal size might mediate the association between satiety responsiveness and weight in children; children with lower Satiety Responsiveness (SR) potentially gain weight as a result of their susceptibility to consuming larger meals. No research to date has examined the behavioural pathway through which children with lower satiety sensitivity gain weight.

8.2 Study aim

The aim of this study was to explore whether meal size (energy consumed per eating occasion) mediates the association between SR and weight in early life.

8.3 Methods

8.3.1 Study population

The sample included 1903 children from the Gemini cohort. Children without diet diary data or without data on the SR subscale of the CEBQ were excluded, as were children who were missing weight data, data on age at diary completion, appetite or weight measurement, maternal education, birth weight and gestational age.

8.3.2 Measures

8.3.2.1 Satiety Responsiveness

The SR subscale from the CEBQ-T was used in this study. **Chapter 3** describes the CEBQ-T and this subscale in more detail.

8.3.2.2 Meal size

The Gemini dietary data was used to classify eating occasions (occasions in which food was consumed, and drinks if consumed alongside food), and meal size was then derived (described in **Chapter 3)**.

8.3.2.3 Anthropometrics and demographics

Details of data collection for anthropometrics and demographics within Gemini can be found in **Chapter 3**. This study included birth weight, birth weight SDS, two year weight and two year weight SDS.

The demographic data included age at data collection (appetite, diet and weight measurement), sex, gestational age, ethnicity (dichotomised into white and non-white) and maternal educational attainment (dichotomised into higher (university level education) and lower (no university education)).

8.3.3 Statistical analyses

Of those children with dietary data (*n*= 2714) 511 were excluded as they had less than three days of diary entries (*n*= 378), were missing data on the SR subscale (*n*= 118), gestational age (*n*= 25), birth-weight (*n*= 45), age at CEBQ completion (n= 102), age at two year weight measurement (*n*= 441) or were missing weight data at two years (*n*= 441). This left a final sample of 1903 children for the mediation analysis. Differences in demographic characteristics between the analysis sample (n= 1903) and non-responders (*n*= 2901) were examined using chi-square and independent samples t tests.

8.3.3.1 Residualised variables

SR scores were residualised for age at CEBQ completion, sex, birth weight and gestational age effects. Meal size was residualised for age at diary completion, sex, birth weight and gestational age, before analyses. Two year weight and weight SDS were both residualised for age at weight measurement, sex, gestational age effects, and birth weight or birth weight SDS respectively.

8.3.3.4 Mediation analysis

The mediation analysis focused on SR and meal size (eating occasions) because **Chapter 7** demonstrated that meal size but not meal frequency was associated with weight gain. **Chapter 6** also demonstrated that FR was not associated with meal size.

Baron & Kenny's (1986) mediation analysis method was used (**Figure 8.1**). Associations among i) satiety responsiveness and meal size, ii) satiety responsiveness and adiposity (indexed using two year weight (kg) and weight SDS), and iii) meal size and adiposity were tested using CSGLMs. All variables were residuals. The Sobel test (Mackinnon et al. 2007; Preacher & Hayes 2004) was used to test whether meal size significantly mediated the association between satiety responsiveness and adiposity.

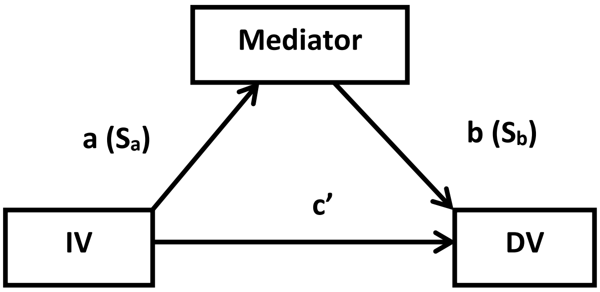

Figure 8.1: A mediation model (Baron & Kenny 1986)

Abbreviations: IV, independent variable; DV, dependent variable

a = regression coefficient for the association between IV (satiety responsiveness) and mediator (meal size).

b = regression coefficient for the association between the mediator (meal size) and the DV (adiposity; two year weight and weight SDS) when the IV (satiety responsiveness) is also a predictor of the DV (adiposity; two year weight and weight SDS).

S_a and S_b are standard errors of path coefficients a and b respectively.

8.4 Results

8.4.1 Sample characteristics

Characteristics of the analysis sample (*n*= 1903) are shown in **Table 8.1**. The mean SR score was 2.68 and the average meal size was 753 kJ. The mean weight of the sample at two years of age was 12.3 kg, and weight SDS was 0.07, close to the UK 1990 population mean of 0 (Cole et al. 1995). The majority of children (83%) were classified as healthy weight for their age and sex, with 17% classified as overweight or obese. Compared with non-responders, there was a slight overrepresentation of children who were younger at the CEBQ and diet-diary completion in the analysis samples. There were also more mothers of white ethnicity and who were educated to a higher level (p-values <0.001).

Table 8.1. Characteristics of the analysis sample (*n*= 952 families, *n*= 1903 children)

	Mediation analysis sample (*n*= 1903)	**Non-responders** (*n*= 2901)	***p*-value**
Sex [*n* (%)]			
Boys	919 (48.3)	1467 (50.6)	0.13[a]
Girls	984 (51.7)	1434 (49.4)	
Ethnicity [*n* (%)]			
White	1830 (96.2)	2632 (90.7)	**<0.001**[a]
Non-white	73 (3.8)	251 (8.7)	
Maternal education [*n* (%)]			
Low	938 (49.3)	1854 (63.9)	**<0.001**[a]
High	965 (50.7)	1047 (36.1)	
Age at CEBQ completion (m)	15.6 (1.0)	15.97 (1.21)[b]	**<0.001**[c]
Age at diet diary completion (m)	20.58 (0.97)	21.10 (1.47)[d]	**<0.001**[c]
Age at weight measurement (m)	24.34 (1.04)	24.39 (1.13)	0.04[c]
Birth weight SDS [mean (SD)]	-0.54 (0.93)	-0.57 (0.96)[e]	0.27[c]
Gestational age (wks) [mean (SD)]	36.20 (2.47)	36.20 (2.50)[f]	0.71[c]
Meal size (kJ) [mean (SD)]	753 (209)	737 (209)[b]	0.76[c]
Satiety Responsiveness (1-5) [mean (SD)]	2.68 (0.63)	2.68 (0.62)[b]	0.87[c]
Body weight at two years (kg) [mean (SD)]	12.30 (1.44)	12.35 (1.58)[g]	0.21[c]
Weight SDS at two years [mean (SD)]	0.07 (1.02)	0.17 (0.38)[g]	0.10[c]
Weight status at two years[h] [*n* (%)]			

Overweight	321 (16.9)	168 (17.5) [i]	0.41 [a]
Healthy weight	1582 (83.1)	793 (82.5) [i]	

Abbreviations: %, percentage; CEBQ, Child Eating Behaviour Questionnaire; m, months; SD, Standard Deviation; wks, weeks; kJ, kilojoules; SDS: Standard Deviation Score

[a] Chi-square test for differences between populations. Significant differences ($p< 0.01$) are shown in bold.

[b] *n*= 1959

[c] Independent samples t-test for mean differences between populations. Significant differences ($p< 0.01$) are shown in bold.

[d] *n*= 811

[e] *n*= 2736

[f] *n*= 2881

[g] *n*= 961

[h] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 321) or healthy weight (*n*= 1582) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as weight SDS ≥1.04 which equates to scores at or above the 85th percentile and healthy weight as SDS< 1.04.

8.4.2 Meal size as a mediator of the association between appetite and adiposity

8.4.4.1 Satiety responsiveness and adiposity

SR showed a negative linear association with weight (B Coefficient, -0.71; 95% CI, -0.49 to -0.92, $p< 0.001$) and weight SDS (B coefficient, -0.75; 95% CI, -0.53 to -0.99, $p< 0.001$), such that children with lower satiety sensitivity were heaver.

8.4.4.2 Meal size and adiposity

Meal size (kJ) showed a significant linear positive association with weight (kg) (B Coefficient, 0.39; 95%CI, 0.16 to 0.62, $p= 0.001$) (**Figure 8.2**) and with weight SDS (B Coefficient, 0.38; 95%CI, 0.15 to 0.62, $p= 0.001$) (**Figure 8.3**). Children who consumed larger meals at 16 months of age were heavier at two years of age.

8.4.4.3 Satiety responsiveness and meal size

SR showed a negative linear association with meal size (B Coefficient, -0.62; 95%CI, -0.40 to -0.85, $p< 0.001$). Including meal size in the regression model to predict weight (kg) from SR attenuated the relationship between SR and weight (model without meal size: B coefficient, -0.71; 95% CI, -0.49 to -0.92, $p< 0.001$; model with meal size: B coefficient, -0.67; 95% CI, -0.45 to -0.88, $p< 0.001$). The change in B coefficient was 0.04, indicating that meal size partially mediated the association between SR and weight, by 5.6% (**Figure 8.2**). The Sobel test confirmed significant mediation of the association between SR and weight (kg) by meal size ($p= 0.03$).

The results were similar for weight SDS (**Figure 8.3**). Including meal size in the model attenuated the relationship between SR and weight SDS (model without meal size: B coefficient, -0.75; 95% CI, -0.53 to -0.99, $p< 0.001$; model with meal size: B coefficient = -0.71; 95% CI, -0.49 to -0.95, $p< 0.001$). The change in coefficient was 0.04 (5.3%) and the Sobel test confirmed that meal size also significantly mediated the association between SR and weight SDS ($p= 0.028$).

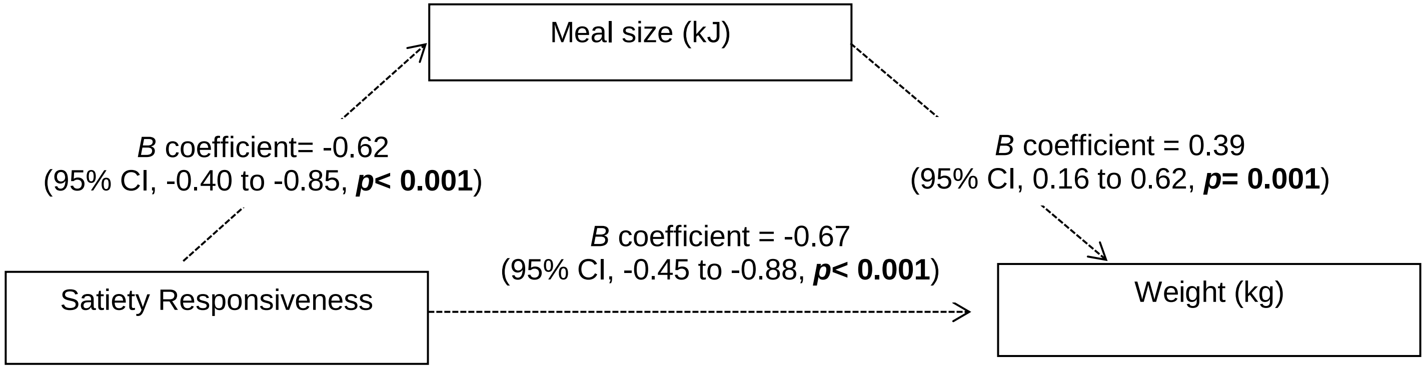

Figure 8.2. Path diagram showing that meal size significantly mediates the association between satiety responsiveness and weight

Abbreviations: *B*, unstandardised beta coefficient; kJ, kilojoules; SDS, standard deviation score
The path diagram shows the simple association between satiety responsiveness at 16 months and meal size at 21 months, the simple association between meal size at 21 months and weight at two years, and the association between satiety responsiveness at 16 months and weight at two years adjusted for meal size at 21 months. The simple association between satiety responsiveness and weight (*B* coefficient, -0.71; 95% CI, -0.49 to -0.92, $p < 0.001$) was slightly higher than the association between satiety responsiveness and weight adjusted for meal size (change in *B* coefficient, 0.04; a decrease of 5.6%), indicating that meal size mediated part of this association. The Sobel test confirmed that meal size significantly mediated the association between satiety responsiveness and weight ($p = 0.026$).

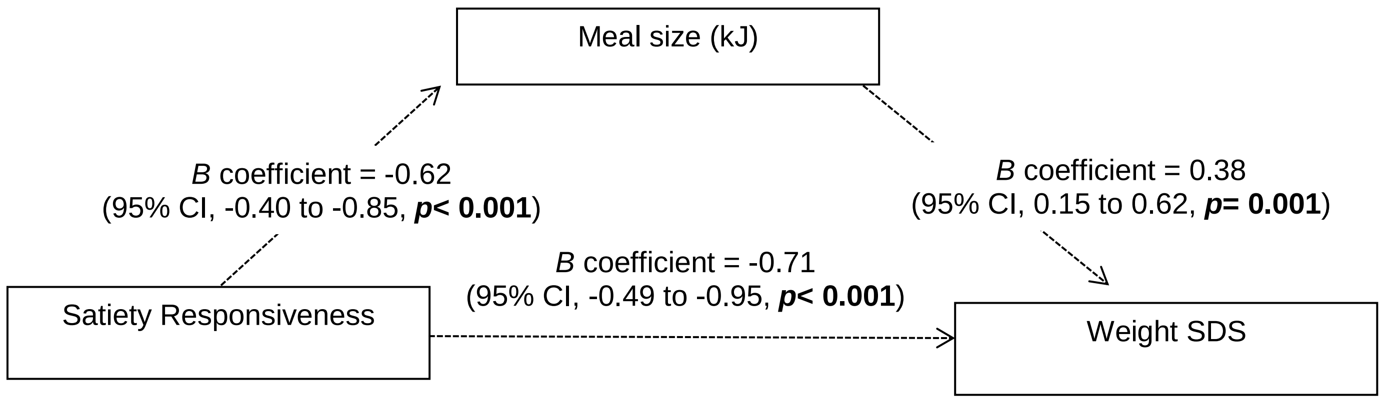

Figure 8.3. Path diagram showing that meal size significantly mediates the association between satiety responsiveness and weight SDS.

Abbreviations: *B*, unstandardised beta coefficient; kJ, kilojoules; SDS, standard deviation score
The path diagram shows the simple association between satiety responsiveness at 16 months and meal size at 21 months, the simple association between meal size at 21 months and weight SDS at two years, and the association between satiety responsiveness at 16 months and weight SDS at two years adjusted for meal size at 21 months. The simple association between satiety responsiveness and weight SDS (*B* coefficient, -0.75; 95% CI, -0.53 to -0.99, $p < 0.001$) was slightly higher than the association between satiety responsiveness and weight SDS adjusted for meal size (change in *B* coefficient, 0.04; a decrease of 5.3%), indicating that meal size mediated part of this association. The Sobel test confirmed that meal size significantly mediated the association between satiety responsiveness and weight SDS ($p = 0.028$).

8.5 Discussion

8.5.1 Summary of findings

This is the first study to explore the behavioural mechanism through which children with lower satiety responsiveness might gain weight. The aim of the study was to explore whether meal size (energy consumed per eating occasion) mediates the association between SR and weight in early life.

It is well established that children with lower SR have a higher weight, and gain weight at faster rate during early life (van Jaarsveld et al. 2011; Parkinson et al. 2010; Deutekom et al. 2016; Disantis et al. 2011; Gregory et al. 2010a; Mallan et al. 2014; Steinsbekk & Wichstrøm 2015; Steinsbekk et al. 2016). What has been unknown until now is *how* they might be gaining weight – the everyday eating behaviours through which SR is expressed at a young age. **Chapter 6** showed that children with lower satiety responsiveness were consuming larger meals, and **Chapter 7** showed that meal size was a driver of weight gain during early childhood. The current study suggests that one behavioural mechanism through which children with lower satiety responsiveness might gain weight is via the consumption of larger meals. However, the mediation effect was small, with meal size explaining approximately 5% of the association between SR and weight in toddlers, indicating that there must be additional pathways leading to weight gain for children low in satiety responsiveness. Energy expenditure was not assessed within the Gemini study, but it is possible that children with lower SR also have a lower energy expenditure. It has been suggested that when individuals are sedentary, appetite is poorly regulated and energy expenditure is reduced, resulting in weight gain (Blundell 2011). This suggests that lower satiety responsiveness and lower energy expenditure may go hand in hand. It is also possible that at this young age, milk drinking is muddying the water; as **Chapter 6** showed that children with higher SR for example consumed less energy during their eating occasions, but drank more frequently. It is worth exploring the mediation of SR and weight by meal size in children at an age when they are on the family diet, rather than during the complementary feeding period.

Nevertheless, lower satiety sensitivity appears to make some children more susceptible to eating more each time they eat, and subsequently susceptible to weight gain. It seems intuitive that children less sensitive to feelings of fullness would consume larger meals in order to feel satiated, and that this greater energy intake would be one pathway to gaining weight. However, this is the first study to have explored these interrelationships.

8.5.2 Implications

This study demonstrates that lower SR, places some children at risk of becoming overweight in the future, partly via consumption of larger meals. This information can be used to develop targeted interventions aimed at preventing excessive weight gain in children who are behaviourally susceptible to obesity.

Satiety responsiveness has a strong genetic basis (Llewellyn et al. 2014), so it seems probable that the tendency of some children to consume larger meals has some genetic basis. However, this does not mean that intervention is not possible. The assessment of appetitive traits in early childhood could identify children with lower SR, and their parents could be offered guidance on appropriate portion sizes. For example, offering smaller portions may mitigate against overeating for children who tend to eat everything on their plate.

As discussed in **Chapter 7** there is very little guidance on portion sizes for young children. The guidance that does exist in the UK suggests that children will adjust their intake according to their appetite level (The Infant and Toddler Forum 2015). The implication of this is that parents should feed to their child's appetite. However, the current study shows that some children may not adjust their intake effectively and may be at risk of overweight as a result. Parents of these children may benefit from specific advice based on their child's appetite such as tailored advice on offering smaller portions and on having a 'no second helpings' policy. The recent suggestion that we need to tackle portion sizes at a policy level, for example reducing portion sizes in restaurants, or reducing the size of tableware (Marteau et al. 2015) might be important for tackling obesity at a population level, but individual differences in eating behaviours also play a role. A two-pronged approach, with policy options targeting at a population health level, but also more individualised guidance provided to some families within the home environment may be beneficial.

8.5.3 Strengths and limitations

SR scores were obtained using a validated psychometric measure, and meal size was computed over three days. Three day food diaries are considered a reasonably reliable measure of habitual intake and health professional measured weights were also available.

There are, however, limitations to the study. This study was cross-sectional and does not enable conclusions to be drawn about the direction of the relationship. It may well be that children with lower SR consume larger meals which results in weight gain, however it could simply be that heavier children have lower SR but consume more because they are heavier. However, SR has been found to predict weight gain prospectively in Gemini (van Jaarsveld et al. 2011), and **Chapter 6** demonstrated that larger meal size predicts weight gain, after adjustment for concurrent weight. Therefore, the most likely explanation is that low SR leads to the consumption of larger meal size which subsequently leads to faster growth.

A second limitation is that the sample was twins, and twins can differ to singletons on some aspects, including early growth; so replication of these findings in singletons would strengthen the findings. **Chapter 4,** however, demonstrated that the Gemini dietary data are comparable to those of children aged one to three years from the NDNS.

The sample of children in this study were relatively young and relationships between appetitive traits, eating patterns and weight might change as children get older. Future work should explore the mediation of appetite and adiposity by behavioural aspects of eating at older ages when children have more autonomy with respect to how often and how much they consume.

8.5.4 Conclusions

Children with lower sensitivity to satiety are at greater risk of excess weight by eating larger portions. This makes low sensitivity to satiety a key area for intervention. Tailored guidance on appropriate portion sizes could be offered to parents of ‘at risk’ children.

Individual differences in eating behaviours and susceptibility to weight gain also need to be explored in later childhood to examine the extent to which appetite and eating patterns play a role in weight trajectories beyond the pre-school years. In order to do this, associations between appetitive traits, consumption patterns and weight could be explored in later childhood. In addition, the same sample of children could be followed up over time to explore the stability and continuity of dietary intake, consumption patterns and appetite from early to mid-childhood.

CHAPTER 9. STABILITY AND CHANGE OF DIETARY INTAKE AND APPETITE FROM EARLY TO MID-CHILDHOOD

9.1 Background

Dietary intake has been shown to track during childhood suggesting that dietary exposure during the early years may influence longer-term food choice and eating behaviour. Studies that have explored the stability of nutrient intakes have demonstrated continuity from early to middle childhood. One longitudinal study of 50 infants explored the consistency of dietary intake from six months to four years of age. 24 hour dietary recalls were completed for each child at six months, one year, two years, three years and four years of age to examine how dietary intake tracked over time. The strongest stability was observed from age two to four years for protein (r= 0.65), sugar (r= 0.39), starch (r= 0.33), fat (r= 0.53) and cholesterol (r= 0.49). Children with higher intakes of energy and nutrients at age two years also tended to have higher intakes at age four years (Nicklas et al. 1991).

Another investigation of 95 children from the Framingham Children's Study explored the stability of nutrient intakes longitudinally over a six-year period. Three day food diaries were completed by parents of children when they were three to four years old and nutrient intakes were compared with those from diaries completed when the children were five to six years old, and seven to eight years old. The strongest correlations over time were found for carbohydrate (r= 0.63 at five to six years and r= 0.57 at seven to eight years) and fat (r= 0.61 at five to six years and r= 0.55 at seven to eight years). Children with the highest intakes maintained them over time (Singer et al. 1995).

Food intake has also shown stability during childhood. Data from ALSPAC for 6177 children was used to characterise dietary patterns at ages three, four, seven and nine years. Three patterns were observed over time: 'processed' (foods with high fat and sugar content, and processed and convenience foods), 'traditional' (meat, poultry, potato and vegetable consumption) and 'health conscious' (salads, fruit, vegetables, fish, pasta and rice) patterns. High correlations from three to nine years of age were observed for all three patterns; 'processed' (r=0.46), 'traditional' (r=0.35 and 'health conscious' (r=0.41). However, intake was assessed using Food Frequency Questionnaires rather than individualised diet diaries (Northstone & Emmett 2008). Nevertheless, it is important to establish whether intakes of food and drinks during early life are stable throughout childhood because if they are then early intervention may result in healthy eating habits that are maintained into later life.

Given that food and nutrient intakes have previously shown some stability over time, it is possible that consumption patterns – meal frequency and meal size - during early life may also track into later childhood. This has never been explored. **Chapter 7** demonstrated that meal size in early life was positively associated with weight gain up to five years of age. If meal size tracks into later childhood, those children consuming large portions as toddlers may continue to do so, with implications for the continuation, or progression, of an overweight trajectory.

In addition to the stability of dietary intake and consumption patterns, the stability of appetitive characteristics is an important area for research especially given that **Chapter 6** demonstrated a role for appetite in how often and how much children eat. Appetitive traits have previously been shown to be relatively stable during childhood. A study which examined continuity in CEBQ scores from age four to 11 years in a sample of British twins showed that children who scored highly on FR at age four also scored highly on FR at 11 years of age (r= 0.44) and children who scored low on SR aged four also scored low on SR aged 11 (r= 0.46) (Ashcroft et al. 2008). However, they also noted a change in appetitive traits such that children became more 'appetitive' as they got older; satiety responsiveness scores reduced over time, and food responsiveness scores increased, suggesting an increased likelihood of children overeating as they get older.

Exploring stability as well as change in dietary intake, appetite and consumption patterns in a young sample is important, given the associations found in this thesis between appetite, consumption patterns and weight gain. It is possible that if children become less satiety responsive over time they subsequently consume even larger meals, and if children become more food responsive over time they eat even more frequently. If meal size and meal frequency are shown to increase with age, this also has implications for weight gain during childhood. These relationships have never been explored.

9.2 Study aim

The aim of this chapter is to explore the stability and change in energy and nutrient intakes, consumption patterns and appetite from early to mid-childhood. Specifically the following aims will be addressed: i) describe the dietary intakes of children in the Gemini cohort at seven years of age, ii) establish stability (tracking) and change in dietary intakes and consumption patterns (meal size and frequency) of children in the Gemini cohort between 21 months of age and seven years of age, and iii) establish stability (tracking) and change in satiety responsiveness and food responsiveness of children in the Gemini cohort between 16 months of age and seven years of age.

9.3 Method

9.3.1 Study population

The Gemini analysis sample included 200 children with complete CEBQ data at 16 months and seven years of age, three days of complete diet data at 21 months and seven years of age, weight data at two and seven years of age, and data on gestational age, birth weight, ethnicity and maternal education.

9.3.2 Measures

9.3.2.1 Dietary intake

The method used for dietary data collection at seven years of age is described in detail in **Chapter 3**. 222 families (79% of those completing three day diaries at seven years) also had dietary data at 21 months of age. Of these, 145 families also had complete data on the CEBQ at 16 months and seven years of age. 100 of these families (*n*= 200 children) were randomly selected to be included in the current study using the ‘Rand()’ function in Excel which assigns random numbers to each family.

9.3.2.2 Consumption patterns

The dietary data was manually coded to classify eating and drinking occasions. The methods used for coding the seven year dietary data was the same as that used at 21 months and has been described in **Chapter 3.** The average meal size and meal frequency among the sample was calculated for consumption occasions, eating occasions and drinking occasions. This process has been described in detail in **Chapter 3.**

9.3.2.3 Appetite

Five of the eight CEBQ subscales (EF, FR, SE, SR, FF) were assessed at seven years of age (**Appendix 3.6.**). The questionnaires were sent to parents between April 2014 and January 2015. In line with the methods used in **Chapter 6**, two subscales were used in this study; 'Food Responsiveness' (FR) and 'Satiety Responsiveness' (SR). Details of each of these subscales and the method used to adapt the CEBQ for use in this study can be found in **Chapter 3.**

9.3.2.4 Anthropometrics and demographics

Details of the data collection for anthropometrics and demographics within Gemini can be found in **Chapter 3**. In brief, the anthropometrics used to characterise the sample within this study included birth weight, birth weight SDS, and seven year height and weight which were used to compute BMI and BMI SDS. The demographic data included age at data collection (appetite, diet and weight measurement), sex, gestational age, ethnicity (dichotomised into white and non-white) and maternal educational attainment (dichotomised into higher (university level education) and lower (no university education)).

9.3.3 Statistical analyses

9.3.3.1 Non-response analyses

Non-response analyses were conducted to compare children in the sample (n= 200) with: i) children who only had complete CEBQ data at 16 months (n= 3149), and ii) children who only had complete three day dietary data at 21 months (n= 2136). The methods for conducting non-response analyses have been described in **Chapter 3**.

9.3.3.2 Power

In order to determine whether the sample of 200 children provided sufficient power to explore stability and change in dietary intake, consumption patterns and appetite over time, post-hoc power calculations were carried out using G-Power (version 3.0.10; Softpedia). These are described in **Chapter 3** but in brief the sample of 200 children provided 99% power to detect a medium effect (r= 0.3) and was therefore sufficient to explore tracking over time.

9.3.3.3 Dietary intake at seven years of age

Dietary intake was coded using the same methods as those for the 21-month data. Average daily energy, macronutrient (total fat, saturated fat, protein, carbohydrate, starch, fibre and sugars[q]) and micronutrient (sodium, vitamin C, thiamine, riboflavin, niacin, folate, vitamin B-12, calcium, vitamin D, vitamin A, and iron) intakes were

[q] Data on sugar components (non-milk extrinsic sugars and intrinsic milk sugars) were not available as it was not requested at the time of diary coding

summarised. Energy and macronutrients were summarised as total grams per day (g/d), and percentage of daily energy intake (%E); micronutrients were summarised as milligrams (mg) or micrograms (µg) per day, including supplements. Descriptive analyses including the mean, SD, minimum, maximum and 25th and 75th percentile scores were computed for all dietary intake variables.

9.3.3.4 Stability and change in dietary intake from 21 months to seven years of age

Daily intakes of energy, macronutrients and micronutrients at seven years of age were compared to those in the same sample of children at 21 months of age.

Dietary variables at both times points were computed as percentages of DRVs for children at two years of age and seven years of age respectively. Change in mean scores across each of the two time points was assessed using Generalized Linear Mixed Models (GLMMs) to adjust for the clustering of twins within families and also adjustment for the difference in age between the two dietary assessment time points. Effect sizes of the change in scores were estimated using Cohen’s d; the mean change score (between age 21 months and seven years) divided by the standard deviation of the initial mean score (Cohen 1992). Comparisons could not be made over time for fat, saturated fat, starch or sugars as no DRVs are available for children aged 21 months on these variables. The stability of energy, macronutrients and micronutrients from 21 months to seven years of age were explored using partial correlation with adjustment for the clustering of twins within families and time difference between diary completion at 21 months and seven years of age.

9.3.3.5 Stability and change in consumption patterns from 21 months to seven years of age

In order to explore change in the size and frequency of eating occasions, drinking occasions and consumption occasions from 21 months to seven years of age, all meal size variables were computed as a percentage of daily energy intake (%E) for consumption occasions, eating occasions and drinking occasions. The difference in mean scores for meal size (%E) and meal frequency at each time point were explored using GLMMs. The difference in age between the two dietary assessment time points was also included as a covariate. Effect sizes of the change in scores were estimated using Cohen’s d (Cohen 1992).

Stability of the size (%E) and frequency of eating occasions, drinking occasions and consumption occasions, from 21 months to seven years of age were explored using partial correlations, with adjustment for clustering and the time difference between diary completion at 21 months and seven years of age. There was a reduced sample of 67 children for all analyses of drinking occasions as this was defined as an occasion in which a drink was consumed that was not water. Therefore only children who consumed drinks with energy content were included.

9.3.3.6 Stability and change in appetite from 16 months to seven years of age

The change in SR and FR from 16 months to seven years of age was explored by comparing the difference in mean scores at each time point using GLMMs. The difference in age between the two CEBQ assessment time points was included as a covariate. Effect sizes of the change in scores were estimated using Cohen's d (Cohen 1992). Stability of SR and FR from 16 months to seven years of age was explored using partial correlations adjusted for twin clustering and the time difference between CEBQ completion at 16 months and seven years of age.

9.4 Results

9.4.1. Sample characteristics

The characteristics of the sub-sample (*n*= 200) for whom dietary data (and FR and SR) were available at both 21 months (and 16 months) and seven years are shown in **Table 9.1**. There were slightly more boys than girls (53.0%) and most children were of white ethnicity (96.0%). Children were on average 84 months old (seven years) at CEBQ completion, diary completion and weight measurement. The prevalence of overweight/obesity (weight SDS≥1.04) at seven years of age among the sample was 6% (*n*= 12).

Table 9.1. Characteristics of the analysis sample

Characteristic	Analysis sample (*n*= 200)
Sex [*n* (%)]	
Boys	106 (53.0)
Girls	94 (47.0)
Ethnicity [*n* (%)]	
White	192 (96.0)
Non-white	8 (4.0)
Maternal education [*n* (%)]	
Low/intermediate	68 (34.0)
High	132 (66.0)
Age at CEBQ completion (m) [mean (SD)]	84.76 (1.39)
Age at diet diary completion (m) [mean (SD)]	84.10 (1.29)
Age at weight measurement (m) [mean (SD)]	84.40 (1.91)
Gestational age (wks) [mean (SD)]	36.63 (2.22)
Weight at birth (kg) [mean (SD)]	2.49 (0.51)
Weight SDS at birth [mean (SD)]	-0.71 (0.92)
BMI (kg/m^2) [mean (SD)]	15.24 (1.27)
BMI SDS [mean (SD)]	-0.34 (0.88)
Weight status[a] [*n* (%)]	
Healthy weight	188 (84.0)
Overweight/obese	12 (6.0)

Abbreviations: %, percentage; m, months; SD, standard deviation; wks, weeks; kg, kilograms; kg/m^2, kilograms per metre squared; SDS, standard deviation score; BMI, Body Mass Index

[a] Weight status at seven years of age was derived using BMI standard deviation scores (SDS). Children were classified as overweight (*n*= 188) or healthy weight (*n*= 12) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as BMI SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as BMI SDS <1.04.

9.4.1.1 Non-response analyses

Table 9.2 compares the characteristics of those with CEBQ data at both time points (n= 200 children), with the sample with CEBQ at 16 months of age only (n= 3149). The analysis sample contained a higher percentage of mothers with a higher education level (p< 0.001) and children with a lower birth weight (p= 0.008).

Table 9.3 compares the characteristics of those with dietary data at both time points (n= 200 children) with the sample with dietary data at 21 months of age only (n= 2136). The analysis sample contained a higher percentage of mothers with a higher education level (p< 0.001) and children with a lower birth weight (p= 0.008).

Table 9.2. Characteristics of the sample with CEBQ data at both time points compared with the sample with CEBQ data at 16 months of age only

	Analysis sample (*n*= 200)	Non-responders (*n*= 3149)	*p*-value
Sex [n (%)]			
Boys	106 (53.0)	1558 (49.5)	0.33[a]
Girls	94 (47.0)	1591 (50.5)	
Ethnicity [n (%)]			
White	192 (96.0)	2967 (94.4)	0.34[a]
Non-white	8 (4.0)	176 (5.6)	
Maternal education [n (%)]			
Low	68 (34.0)	1852 (58.8)	**<0.001**[a]
High	132 (66.0)	1297 (41.2)	
Birth weight SDS [mean (SD)]	-0.71 (0.92)	-0.53 (0.93)	**0.008**[b]
Gestational age (wks) [mean (SD)]	36.63 (2.22)	36.20 (2.50)	0.01[b]

Abbreviations: %, percentage; SDS, standard deviation scores; SD, standard deviation; wks, weeks;
[a] Chi-square test for differences between populations. Significant differences (*p*-value <0.01) are shown in bold.
[b] Independent samples t-test for mean differences between populations. Significant differences (*p*-value <0.01) are shown in bold.

Table 9.3. Characteristics of the sample with dietary data at both time points compared with the sample with dietary data at 21 months of age only

	Analysis sample (*n*= 200)	Non-responders (*n*= 2136)	*p*-value
Sex [n (%)]			
Boys	106 (53.0)	1051 (49.2)	0.33[a]
Girls	94 (47.0)	1085 (50.8)	
Ethnicity [n (%)]			
White	192 (96.0)	2030 (95.0)	0.34[a]
Non-white	8 (4.0)	98 (4.6)	
Maternal education [n (%)]			
Low	68 (34.0)	1126 (52.7)	**<0.001**[a]
High	132 (66.0)	1010 (47.3)	
Birth weight SDS [mean (SD)]	-0.71 (0.92)	-0.53 (0.93)	**0.008**[b]
Gestational age (wks) [mean (SD)]	36.63 (2.22)	36.13 (2.51)	**0.01**[b]

Abbreviations: %, percentage; SDS, standard deviation scores; SD, standard deviation; wks, weeks;
[a] Chi-square test for differences between populations. Significant differences (*p*-value <0.01) are shown in bold.
[b] Independent samples t-test for mean differences between populations. Significant differences (*p*-value <0.01) are shown in bold.

9.4.2 Dietary intake at seven years of age

Average daily energy and nutrient intakes from food, drinks and supplements for the Gemini sample at seven years of age are shown in **Table 9.4**. Daily energy intake was 6155 kJ; this comprised 12% energy from protein, 56% energy from carbohydrate, and 33% energy from fat. Children consumed 14% of energy from saturated fat, 26% of energy from sugars and consumed 1 g/d of fibre. Vitamin D intake was 2.9 µg/d and iron intake 8.64 mg/d. Vitamin C intake was 97 mg per day, calcium intake was 796 mg per day and sodium intake was 1544 mg/d.

9.4.3 Stability and change in dietary intake from 21 months to seven years of age

9.4.3.1 Change in intake between 21 months and seven years of age

Table 9.4 compares the energy, macronutrient and micronutrient intakes of the Gemini sample at 21 months of age with those of the same children at seven years of age. Mean daily energy intakes, as a percentage of the DRVs at each age were compared and show that while at 21 months children were exceeding the DRV for daily energy intake (108%), at seven years, children's average daily energy intake fell below the DRV (93%) and this was a significant difference ($p < 0.001$). The effect size ($d = 1.0$) demonstrates that the change in daily energy intake was large. Similarly, at seven years, protein intake as a percentage of the DRV at seven years of age was 187% compared to 279% at 21 months of age ($p < 0.001$), with a very large effect size ($d = 1.9$). Therefore, while at both ages protein intake was significantly higher than recommended, it was a lower percentage at seven years than 21 months. Carbohydrate intake however was higher at seven years than at 21 months of age (112% of the DRV versus 103%, $p < 0.001$). Children at seven years of age consumed a greater amount of dietary fibre than they were at 21 months, however, the effect size was relatively small ($d = 0.3$). The average intake of dietary fibre did not meet the DRV at either time point (55% and 59% of the DRV respectively). Sodium intake was far higher than recommended at both ages (214% and 129% of the DRV) although at seven years it was significantly lower than at 21 months ($p < 0.001$) as demonstrated by the large effect size ($d = 1.7$). There were significant differences between the two groups on all micronutrients except vitamin A ($p = 0.62$). Vitamin C intake, thiamine, niacin and iron were significantly higher at seven years than at 21 months (p-values all< 0.001), but riboflavin, folate, vitamin B12 and calcium were all significantly lower (p-values all< 0.001). At both ages, all micronutrient intakes exceeded the DRVs, except for iron at 21 months which fell below the recommended intake (6.3 versus 6.9 mg/d).

Table 9.4. Change in energy and nutrient intake from food, drinks and supplements for children in the Gemini sample at 21 months of age and at seven years of age

	21 months old		Seven years old			
Dietary intake	**DRV**	**Mean**[a] (% of DRV)	**DRV**	**Mean**[a] (% of DRV)	***p*-value**[j]	**Cohen's d**
Daily energy intake (kJ)	4050[b]	4372 **(108)**	6653[c]	6155 **(93)**	**<0.001**	1.0
Total fat (g/d)	-	43	-	54	-	
Total fat (%E)	-	36	35 [e]	32.8 (94)	-	
Saturated fat (g/d)	-	21	-	23	-	
Saturated fat (%E)	-	8	11[e]	13.7 (125)	-	
Protein (g/d)	14.5[d]	40 **(279)**	28.3[e]	53 **(187)**	**<0.001**	1.9
Protein (%E)	-	12	15[e]	11.6 (77)	-	
Total carbohydrates (g/d)	-	134	-	206	-	
Total carbohydrates (%E)	50[f]	51 **(103)**	50[g]	56.2 **(112)**	**<0.001**	0.8
Starch	-	62	-	110	-	
Starch (%E)	-	24	-	30.0	-	
Total sugars (g/d)	-	71	-	96	-	
Total sugars (%E)	-	27	-	26.1	-	
Dietary fibre as NSP(g/d)	15[f]	8 **(55)**	20[g]	11.8 **(59)**	**<0.001**	0.3
Sodium (mg/d)	500[h]	1068 **(214)**	1200[i]	1544 **(129)**	**<0.001**	1.7
Vitamin C (mg/d)	30[d]	61 **(203)**	30[e]	97 **(323)**	**<0.001**	0.9
Thiamine (mg/d)	0.5[d]	0.9 **(183)**	0.7[e]	1.4 **(200)**	**<0.001**	0.3
Riboflavin (mg/d)	0.6[d]	1.7 **(283)**	1.0[e]	1.5 **(153)**	**<0.001**	1.9

Niacin (mg/d)	8[d]	10.0 **(124)**	12[e]	24.7 **(109)**	**<0.001**	0.4
Folate (µg DFE/d)	70[d]	163 **(232)**	150[e]	200 **(133)**	**<0.001**	2.0
Vitamin B-12 (µg/d)	0.5[d]	4.4 **(870)**	1.0[e]	4.1 **(412)**	**<0.001**	1.7
Calcium (mg/d)	350[d]	856 **(245)**	550[e]	796 **(145)**	**<0.001**	1.9
Vitamin D (µg/d)	7[d]	2.0 (29)	-	2.9 (-)	-	
Vitamin A (µg RAE/d)	400[d]	606 (151)	500[e]	778 (156)	0.62	0.1
Iron (mg/d)	6.9[d]	6.3 **(92)**	8.7[e]	8.6 **(99)**	**0.001**	0.3

Abbreviations: DRV, Dietary Reference Value; %, percentage; kJ, kilojoules; g/d, grams per day; %E, percentage of daily energy intake; NSP, Non-Starch polysaccharides; mg/d, milligrams per day; µg/d, micrograms per day; DFE, Dietary Folate Equivalent; RAE, retinol activity equivalent

[a] Mean intake including supplements

[b] DRV for daily energy intake is based on the Scientific Advisory Committee on Nutrition (2011) estimated average requirements (EARs) for children two years of age and the mid-point of DRV for males (4201 kJ/d) and females (3899kJ/d) (Scientific Advisory Committee on Nutrition 2011)

[c] DRV for daily energy intake is based on the Scientific Advisory Committee on Nutrition (2011) estimated average requirements (EARs) for children seven years of age and the mid-point of DRV for males (6899 kJ/d) and females (6401 kJ/d) = 6653 kJ per day

[d] DRV for children 1-3 years of age from Department of Health, *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*, HMSO, 1991(Department of Health 1991)

[e] DRV for children seven to 10 years of age from Department of Health, *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*, HMSO, 1991

[f] RNI for children 2-5 years of age from Scientific Advisory Committee on Nutrition (2015)(Scientific Advisory Committee on Nutrition 2015a)

[g] DRV for children five to10 years of age from Scientific Advisory Committee on Nutrition (2015)

[h] DRV for children 1-3 years of age from Scientific Advisory Committee on Nutrition (2003)(Scientific Advisory Committee on Nutrition 2003)

[i] DRV for children seven to 10 years of age from Scientific Advisory Committee on Nutrition (2003)

[j] Paired t-tests were used to test for difference in % DRV scores at each time point. Significant differences are shown in bold.

9.4.3.2 Stability of intake between 21 months and seven years

Table 9.5 shows the correlations between 21 months and seven years for energy and nutrient intakes. Daily energy intake at 21 months showed a small to medium positive association with daily energy intake at seven years (r= 0.23, p= 0.001). Carbohydrate intake showed no association across the two time points (p= 0.25) and protein intake showed a medium positive association (r= 0.29, p< 0.001). Dietary fibre intake showed a strong positive correlation across the two time points (r= 0.47, p< 0.001). The association between sodium intake at 21 months and seven years was positive and a medium sized association (r= 0.28, p< 0.001). Of the micronutrients, vitamin C, thiamine, niacin, folate and iron showed positive associations across the age groups. Riboflavin, vitamin B-12, calcium and vitamin A were not correlated over time.

Table 9.5. Correlations between energy and nutrient intakes at 21 months and seven years of age

DIETARY INTAKE	***r***	***p*-value**[a]
Daily energy intake (kJ)	0.23	**0.001**
Protein (g/d)	0.29	**<0.001**
Total carbohydrates (%E)	-0.08	0.25
Dietary fibre as NSP(g/d)	0.47	**<0.001**
Sodium (mg/d)	0.28	**<0.001**
Vitamin C (mg/d)	0.24	**0.001**
Thiamine (mg/d)	0.43	**<0.001**
Riboflavin (mg/d)	0.13	0.06
Niacin (mg/d)	0.27	**<0.001**
Folate (µg DFE/d)	0.23	**0.001**
Vitamin B-12 (µg/d)	0.05	0.95
Calcium (mg/d)	0.09	0.23
Vitamin A (µg RAE/d)	0.04	0.57
Iron (mg/d)	0.22	**0.002**

Abbreviations: kJ, kilojoules; g/d, grams per day; %E, percentage of daily energy intake; NSP, Non-Starch polysaccharides; mg/d, milligrams per day; µg/d, micrograms per day; DFE, Dietary Folate Equivalent; RAE, retinol activity equivalent

[a] *P*-value for significant correlation between dietary intake at 21 months and seven years of age. Significant differences (p< 0.01) are shown in bold. Analyses were adjusted for the clustering of twins within families

9.4.4 Stability and change in consumption patterns from 21 months to seven years of age

9.4.4.1 Change in consumption patterns between 21 months and seven years

Table 9.6 compares the average meal size and frequencies at 21 months with those at seven years. There were significant differences across the two time points for all variables except the frequency of eating occasions; at both time points children ate on average five times per day ($p= 0.06$). However, the frequency with which they drank differed; with children drinking more frequently at 21 months (1.7 times per day) than at seven years of age (0.3 times per day) ($p< 0.001$). The effect size for the change in drinking frequency over time was very large ($d= 1.7$). As expected this meant that the frequency of consumption occasions (eating and drinking occasions combined) differed by age; with children eating and drinking more often at 21 months (6.7 times per day) than at seven years (5.2 times per day) ($p< 0.001$) and again this effect was large ($d= 1.3$).

Meal sizes also differed according to age. At 21 months children consumed a greater proportion of daily energy intake during each drinking occasion (9.7%) than at seven years of age (3.3%) ($p< 0.001$). The effect size of this difference was large ($d= 1.9$) Children at 21 months also consumed a lesser proportion of daily energy intake during each eating occasion (17.2%) than they did at seven years of age (20.8%) ($p< 0.001$) and again the effect size was large ($d= 1.3$). This finding is perhaps unsurprising given that at 21 months children were consuming a larger proportion of energy from drinks (milk). However, this additional 3.6% of energy intake per eating occasion at seven years suggests that as children get older they consume larger amounts of energy during each eating occasion (20.8% versus 17.2%, $p< 0.001$), as at both 21 months and at seven years of age children were eating five times per day. This meant that overall the meal size per consumption occasion (eating and drinking occasions combined) was higher at seven years (19.9%) than at 21 months (15.5%). In other words, children’s meal sizes (kJ) from eating (rather than drinking) increased with age.

Table 9.6. Change in mean meal size and meal frequency between 21 months and seven years of age

	21 months old		**Seven years old**			
	Mean (SD)	%E (SD)	Mean (SD)	%E (SD)	***p*-value**[a]	**Cohen's *d***
MEAL SIZE (kJ)						
Meal size (consumption occasion)[b]	674 (167)	**15.5 (3.4)**	1224 (318)	**19.9 (3.9)**	**<0.001**	1.2
Meal size (eating occasion)[c]	749 (205)	**17.2 (4.0)**	1273 (305)	**20.8 (4.0)**	**<0.001**	0.9
Meal size (drinking occasion)[d]	418 (159)	**9.7 (3.8)**	196 (163)	**3.3 (2.8)**	**<0.001**	1.9
MEAL FREQUENCY (times per day)						
Meal frequency (consumption occasions)[b]	**6.7 (1.3)**	-	**5.2 (1.0)**	-	**<0.001**	1.3
Meal frequency (eating occasions)[c]	5.1 (0.9)	-	4.9 (0.9)	-	0.06	0.2
Meal frequency (drinking occasions)[d]	**1.7 (1.0)**	-	**0.3 (0.5)**	-	**<0.001**	1.8

Abbreviations: SD, standard deviation; %E, percentage of daily energy intake; kJ, kilojoules
[a] P-value for difference on consumption pattern variables between 21 months and seven years of age. %E has been compared for meal size variables. Significant differences (p< 0.01) are shown in bold.
[b] A consumption occasion refers to an eating or drinking occasion. Drinking occasions in which water was consumed have been excluded.
[c] An eating occasion refers to an occasion in which food was consumed (and drinks if consumed with food)
[d] A drinking occasion refers to an occasion in which a drink was consumed on its own (without food). Drinking occasions in which water was consumed have been excluded, leaving a sample of 67 children.

9.4.4.2 Stability of consumption patterns between 21 month and seven years

Table 9.7 shows the correlations between meal sizes and frequencies from 21 months and seven years. Significant and positive associations indicate that stability was observed for the size and frequency of eating occasions. Children consuming a large proportion of daily energy intake during each eating occasion at 21 months of age, also did so at seven years of age (r= 0.23, p= 0.001), and children that ate frequently at 21 months, tended also to do this at seven years of age (r= 0.31, p< 0.001). The size and frequency of drinking occasions however did not show stability over time, so those children drinking a large proportion of their daily energy intake every time they drank (r= 0.19, p= 0.12) or those drinking often at 21 months (r= 0.19, p= 0.013) did not continue to do so at seven years. However, overall, the size of eating and drinking occasions combined (consumption occasions) did show stability (r= 0.22, p= 0.002). Neither the frequency of drinking occasions (r= 0.18, p= 0.013) nor frequency of consumption occasions (r= 0.18, p= 0.011) showed stability from 21 months to seven years of age.

Table 9.7 Correlations between meal size and meal frequency at 21 months and seven years of age

CONSUMPTION PATTERNS	*r*	***p*-value** [a]
MEAL SIZE (%E)		
Meal size (consumption occasion)[b]	0.22	**0.002**
Meal size (eating occasion) [c]	0.23	**0.001**
Meal size (drinking occasion) [d]	0.19	0.12
MEAL FREQUENCY (times per day)		
Meal frequency (consumption occasions)[b]	0.18	0.011
Meal frequency (eating occasions) [c]	0.31	**<0.001**
Meal frequency (drinking occasions) [d]	0.18	0.013

Abbreviations: %E, percentage of daily energy intake.
[a] P-value for significant correlation between meal size and meal frequency variables at 21 months and seven years of age. Significant differences (p< 0.01) are shown in bold. Analyses were adjusted for the clustering of twins within families
[b] A consumption occasion refers to an eating or drinking occasion. Drinking occasions in which water was consumed have been excluded.
[c] An eating occasion refers to an occasion in which food was consumed (and drinks if consumed with food)
[d] A drinking occasion refers to an occasion in which a drink was consumed on its own (without food). Drinking occasions in which water was consumed have been excluded.

9.4.5 Stability and change in appetite from 16 months to seven years of age

9.4.5.1 Change in appetitive traits between 16 months and seven years

There was no difference in mean scores for SR from 16 months (mean= 2.7, SD= 0.6) to seven years (mean= 2.6, SD= 0.6, *p*= 0.95, *d*= 0.2), but there was a significant difference in FR means scores between 16 months (mean= 2.2, SD= 0.8) and seven years (mean= 2.5, SD= 0.8) (*p*< 0.001), such that children became more food responsive with age. The effect size for the change in FR over time was small to medium (*d*= 0.4).

9.4.5.2 Stability of appetitive traits between 16 months and seven years

Both appetitive traits showed stability over time, demonstrated by a significant positive and medium sized correlation between SR at 16 months and at seven years of age (*r*= 0.29, *p*< 0.001). There was also a large significant positive correlation between FR at 16 months and FR at seven years (*r*= 0.51, *p*< 0.001). Children scoring highly on each trait at 16 months also scored highly at seven years of age.

9.5 Discussion

9.5.1 Summary of findings

This chapter describes the stability and change in dietary intake, consumption patterns and appetite from early to mid-childhood in a sample of 200 British children.

The average daily energy intake for the Gemini sample at seven years of age (*n*= 200) was 7% below that recommended by the SACN (Scientific Advisory Committee on Nutrition 2011). This is in contrast to the average intake for the same children at 21 months, which exceeded the DRV by 8%. This difference might reflect a positive change to the diets of young children in response to concerns surrounding obesity and health in recent years. However it might also reflect under-reporting which tends to be more common in older children than younger children (Macdiarmid & Blundell 1998; Livingstone et al. 2004). This may also reflect the higher SES sample providing data at both time points; these parents may have greater knowledge of healthy eating guidelines and subsequently their children have lower daily energy intakes. Nevertheless, daily energy intake at 21 months was correlated with intake at seven years, suggesting that those with higher intakes in early life continue to have higher intakes in later childhood.

Protein intake at seven years of age exceeded the recommended intake by 87%, but at 21 months it exceeded the DRV by 179%. It is possible that this difference over time might be due to a greater proportion of energy intake from drinks, and predominantly milks, during toddlerhood. It has previously been demonstrated in Gemini that milk was the largest source of protein at 21 months of age (Pimpin et al. 2015). In the current study 66% of children consumed no energy from drinks alone at seven years of age, and the average energy intake per drink occasion was 196 kJ (3.3%E) compared to 418 kJ (9.7%E) at 21 months. Together, this suggests that many children were drinking milk as a drink at 21 months but water as a drink at seven years of age. Nevertheless, protein intake showed continuity with age; children with high protein intakes at 21 months also had high intakes at seven years. The percentage of carbohydrate was higher at seven years than 21 months which again suggests that food and drink sources may be different in later childhood than in early childhood. It is possible that the high carbohydrate intake observed at seven years was consumed in simple carbohydrates (sugar) as within the Gemini sample at seven years of age over a quarter of energy intake was consumed in sugars. Items such as sugar sweetened beverages have been linked to excess weight gain in children (Malik et al. 2006) but also items such as fruit contain a large amount of natural sugar. It is important to explore the sources of carbohydrate during childhood. There was no correlation between carbohydrate intake at 21 months and seven years, suggesting perhaps that dietary changes take place during mid-childhood. This is worthy of further exploration, as are the implications of a diet high in carbohydrate.

The stability observed in almost all dietary intake variables over time from 21 months to seven years concurs with previous research. Nicklas et al (1991) demonstrated consistency in daily energy intake, protein, carbohydrate, fat and cholesterol during early life among 50 infants. 24 hour dietary recalls were completed for each child at six months, one year, two years, three years and four years of age and the strongest tracking was seen from age two to four years. Children with high energy and nutrient intakes at two years of age also had high intakes at four years of age (Nicklas et al. 1991). Nutrient intake has also been shown to track from three to four years of age through to seven to eight years of age (Singer et al. 1995). The findings in the current study highlight the importance of establishing healthy habits early in life as dietary exposure during the early years appears to influence longer-term dietary intake.

This is the first study to explore the stability and change in consumption patterns (meal size and frequency) during early childhood and it has demonstrated that meal size appears to increase with age. Children consumed a greater proportion of energy each time they ate at seven years of age compared to 21 months of age, but did not eat at a lesser frequency; children ate approximately five times per day at both 21 months and seven years. It is worth exploring in more detail *how* older children consume larger meals. At seven years of age children consumed a smaller proportion of energy intake per drinking occasion, which might partially explain why they consumed more energy per eating occasion; drinks (milk) are displaced with food as children get older. Overall with eating and drinking occasions combined they were consuming larger meal sizes at seven years than at 21 months, but this might be expected given that they have higher energy needs.

There were significant positive correlations over time for the size of eating occasions suggesting that larger meal sizes are maintained as children get older. Children who consume larger amounts in early life each time they eat appear to continue to do so as they get older. **Chapter 7** demonstrated that meal size is a critical driver of weight gain during early childhood, and therefore the continuity in meal size has implications for future weight gain into later childhood and adolescence. If children continue to eat larger meals, it can be hypothesised that they might continue to gain weight, placing them at risk of future health problems.

There has been some research to suggest that the portion sizes of commonly eaten foods have increased over time. A study of individuals in the CSFII aged two years and older compared the portion sizes (g) of 170 commonly consumed foods from 1989-1991 and then again from 1994-1996. Increases were seen in a third of foods including grains, cereals and drinks. However, the study is limited as the dietary assessment methods varied at each time point. In 1989-1991 dietary data was collected over three consecutive days, with a 24-hour recall on the first day followed by day two and day three records. In 1994-1996, two non-consecutive 24-hour recalls were collected three to 10 days apart. These methodological differences in assessment may have introduced error. Also, only the weight of the eating occasion was compared, and there was no account taken of the energy content consumed.

Another study of the CSFII looked at trends in portion sizes consumed from 1977-1978 to 1989-1991, 1994-1996, and 1998 and explored both the weight and energy content of meals, snacks and a number of food items. The sample consisted of 63380 individuals aged two years and older. Increases in portion sizes and energy content of meals and snacks were observed over time. Portion sizes increased for salty snacks, desserts, soft drinks, fruit drinks, fries, hamburgers, cheeseburgers, and Mexican food both inside and outside of the home (McConahy et al. 2002). Again though, the dietary assessment methods changed over the course of the study which may have influenced the findings.

There is evidence to suggest that children consume more energy when they are served larger portions (Ramsay et al. 2013; Fisher, Liu, et al. 2007; McConahy et al. 2004) and there is also evidence to suggest that the serving sizes of foods have increased over time. One study explored changes in serving sizes of foods from 1970-2000 in the most popular take-out establishments, fast-food outlets, and family- type restaurants, as well as marketplace foods such as white-bread, cakes, alcoholic beverages, steak, and sodas that in the US. They found that with the exception of sliced white bread, all of the food portions exceeded American guidelines for standard portions and increased over time (Young & Nestle 2002).

The difference in drinking patterns observed over time in the current study is interesting as not only did older children consume less energy each time they drank, but they also drank less often. It is possible that older children were consuming drinks with food and therefore they would not have been reported as separate drink occasions. Also, parents may have either omitted to report drink occasions at seven years of age, or were not always aware when their child had a drink as children have more autonomy by this age. It is however also likely that the difference in drinking patterns is a result of the age of the samples. **Chapter 4** demonstrated that children at 21 months old were still consuming large quantities of milk, and this does not appear to track over time. There was no correlation between the size of drinking occasions from 21 months to seven years of age. This helps to partly explain the findings in **Chapter 6** in which there was no longitudinal association between the meal size of drinking occasions and weight gain; drinking patterns appear to change as children get older. One reason why drinking habits might be more resilient to change than eating habits is likely to be due to the role of milk in young children's diets; at 21 months old 25% of the children's energy intake was consumed in milk as it was during the complementary feeding period. As children get older, milk is not required in such quantities, and other drinks such as water and squash are potentially more likely to be consumed as a drink than milk.

Intuitively therefore, a key area for intervention in early life is the size of eating occasions. Eating patterns appear to track over time; children continue to eat five times per day, but children who ate large meal sizes at 21 months continue to eat larger meal sizes at seven years of age.

Given that meal size appears to track over time, and has been shown to be associated with weight gain, it is important to identify children that might be at risk of overweight due to the consumption of large meals in early life. **Chapter 6** demonstrated that children with lower SR consume larger meals in early life so there is a need to identify whether SR also tracks over time. Indeed, the current study suggests that it does; children with lower scores for SR at 21 months also had lower scores at seven years of age. Children did not, however, become more or less satiety responsive with age. This is in contrast to findings by Aschroft et al (2008) who found that a sample of 322 children became less satiety responsive from four to 11 years of age (Ashcroft et al.,2008). This contrast might be due to the difference in the age of the samples, or the smaller sample size of the current study which reduced the power to detect small differences.

Interestingly, FR not only showed continuity over time; with those scoring high on FR at 21 months also scoring high on FR at seven years, but FR also increased with age. Children became more food responsive as they got older which could be due to the trait being better expressed in older children who have more autonomy over their eating.

9.5.2 Implications

This study suggests that dietary intake and consumption patterns track modestly from early life to mid-childhood. The implications of which are that it is important to establish healthy eating habits early in life that will be maintained as children get older. Children with higher intakes of energy, fat, protein, carbohydrate and sodium during toddlerhood continue to have higher intakes in later childhood and this has the potential to put them at risk of excess weight gain and other health conditions. It is important that parents have guidance on healthy eating in order to ensure that they set their child on the path to a healthy life.

Children consuming larger meals and those who eat frequently during toddlerhood continue to do so up to the age of seven. **Chapter 7** however highlighted that larger meals were associated with weight gain in children. The continuity in meal size highlights the importance of parents knowing appropriate portion sizes for infants, toddlers and children. Serving size influences intake; with larger portion sizes leading to greater intake (Rolls et al. 2000; Savage, Fisher, et al. 2012). It is possible that large servings at a young age might shape children's perceptions about what is an appropriate amount to eat and shape their eating habits in later life.

This study has also shown that appetitive traits – FR and SR – show continuity during childhood. Children exhibiting lower SR and/or higher FR in early life continue to do so and these traits have been associated with greater meal size and greater eating frequency respectively. As children get older and have more autonomy over food choices, parents may need guidance to provide an environment that will minimise opportunities for the expression of appetitive traits that might result in excess weight gain.

9.5.3 Strengths and limitations

This study is one of very few studies to have collected longitudinal diet diary data, at two time points for the same sample of children. Tracking the same children over time gives insight into how early life eating behaviours might shape future eating behaviours. This study is the first to explore the stability and change in consumption patterns (meal size and frequency) in children and has highlighted the importance of healthy habits being formed at a very young age if children are to follow a healthy weight trajectory.

A strength of the study is that at both time points the same measures were used; the CEBQ, diet diaries and portion guides were in the same format, and the dietary assessment software (DINO) (Fitt et al. 2014) was also the same. The coding of dietary data was carried out in an identical manner, by the same coder at both time points. This would have helped to minimise methodological errors. Also, on both occasions, the same parents completed the CEBQ and diet diaries. This could also, however, be a limitation; parents might simply be recalling their previous responses. This is, however, unlikely over a five year period, and the changes over time, such as the increase observed in FR scores, and increase in meal sizes, suggest that parents were not simply reporting from memory. Nevertheless, the estimates of continuity over time may be inflated by the shared methods and shared observers at both time points.

The main weakness of the study is the relatively small sample size (*n*= 200). This was due to financial restraints limiting the number of diaries for coding. Had the finances been available, the cohort nature of the study and the time between each measurement (five years) might have meant that drop-out would have limited the numbers anyway. Nevertheless, 200 children provided sufficient power to track the same sample of children over time, and 200 children was a reasonable response rate given that there was a difference of five years between measurements. There were differences between the sample characteristics and non-responder characteristics; with the better educated parents continuing to participate and this might have resulted in more favourable intakes at seven years of age as parents have more knowledge of recommendations.

The sample was twins and therefore the findings would need to be replicated in a sample of singletons to assess how generalizable they are to the general population. The clustering of twins within families; parents serving the same food to both children for example, might also have influenced findings, but analyses did adjust for the clustering.

Under-reporting has been found to be a methodological issue in older children (Huang et al. 2004; Livingstone et al. 2004; Weden et al. 2013) and this might explain why some intakes were more in-line with DRVs at seven years, such as daily energy intake falling below the DRV. The cohort nature of the Gemini study might also have impacted on the findings, for example, the proportion of overweight children at seven years (12%) was lower than at 21 months (17%). Attrition might be expected to be highest among the overweight, but it might help to explain why for example daily energy intakes were lower at seven years than 21 months.

9.5.4 Conclusions

This study has demonstrated that energy and nutrient intake, consumption patterns and appetitive traits in early life show modest continuity over time. Children consuming higher intakes of energy and nutrients, those eating larger amounts and those eating more frequently tend to continue to do so as they get older. In addition, meal sizes get larger from early to mid-childhood, which might reflect higher energy requirements but equally might have implications for excess weight gain. Some children appear to be more susceptible to consumption of larger meals than others, and the appetites of these children show continuity over time. Seemingly children will not ‘grow out of’ their eating habits. This highlights the importance of establishing a healthy diet and eating habits in early life which will continue into later childhood, potentially shaping weight trajectories. Also, it suggests that perhaps identifying children 'at-risk' of overconsumption early in life would prevent excess weight gain.

CHAPTER 10. CONCLUDING DISCUSSION

10.1 Summary of thesis findings

The overall aim of this thesis was to identify behavioural pathways through which individual differences in appetite may result in weight gain. I carried out a number of innovative analyses to address this aim and to fill gaps in the literature. My thesis provides additional support for the behavioural susceptibility theory of weight gain; that individuals with a more avid appetite, characterised by lower sensitivity to satiety and/or higher responsiveness to food cues, are more likely to overeat in response to the food environment (Carnell & Wardle 2008).

The dietary intakes of 2336 twins aged 21 months were described in **Chapter 4**, and have been shown to be comparable to those of a nationally representative sample of singletons aged 18-36 months. This highlights that the Gemini dietary data utilised throughout my PhD is largely representative of the UK population and a valuable resource for assessing aspects of young children's eating behaviour. Dietary intakes in the Gemini sample were also compared to Dietary Reference Values for children aged two years. Findings demonstrated that young children in the UK are consuming excess energy, and have high protein intakes. Sodium intake is extremely high and the majority of young children are not consuming sufficient vitamin D. Young children were also still consuming a large proportion of their energy intake in milk, and almost 15% of the sample were still consuming formula milks, at an age when weaning should be close to completion.

The relatively high energy intake and protein consumed in milks, and the use of formula milks beyond the recommended 12 months of age warranted further exploration. **Chapter 5** sought to identify whether extending formula milk feeding to 21 months of age was associated with increased energy intake and higher weight gain during early childhood. In fact, this study demonstrated that compared to children consuming no formula milk, those who were consuming formula did not consume more energy per day and were not heavier. The reason for this appeared to be because they consumed more milk but less food, and formula milk seemingly acted as a substitute for, rather than an addition to, energy from solid foods. With the use of data from the CEBQ and interviews with a sub-sample of mothers who continued with formula feeding until at least 21 months, this study was able to conclude that this difference in consumption behaviour appeared to be due to appetite; children with less avid appetites and subsequently lower intakes of solid food were fed formula milk by their mothers in order to compensate for the lack of energy intake.

The behavioural susceptibility model proposes that individuals who exhibit ‘high-risk’ appetitive traits are more likely to over-eat and gain weight. However, until now, the role of appetite in eating behaviour within an everyday context has not been determined. **Chapter 6** identified key aspects of appetite associated with specific consumption patterns, which subsequently could place some children at greater risk of overweight than others. Children with higher food responsiveness ate more frequently (higher ‘meal frequency’) than children with lower food responsiveness, and children with lower satiety responsiveness consumed more energy each time they ate (larger ‘meal size’) than those with higher satiety responsiveness. There is the potential for each of these eating behaviours to result in overconsumption.

Determining the dietary pathways towards overweight in young children is important to enable early intervention and help shape healthy eating habits and a healthy weight trajectory. There has been a good deal of research into the types of food and drinks that might lead to weight gain, for example comparisons between formula milk and breast milk (Baird et al. 2008), the influences of sugar sweetened beverages (Collison et al. 2010), as well as comparisons between different dietary patterns and their associations with weight (Nicklas et al. 2003). *How* children eat however has received less interest, but might be just as important as *what* they eat for determining weight trajectories. **Chapter 7** demonstrated that the patterning of energy intake plays a role in weight gain. Children with high meal sizes gained weight at a faster rate from 21 months to five years of age than children consuming smaller meals. Interestingly though meal frequency had no impact on weight gain. The findings suggest that contrary to the widely held belief that young children will regulate their energy intake, not all children do so. Some children are more at risk of weight gain than others, in particular those children who consume large meals. In combination with the findings from **Chapter 6** that children with lower SR consume larger meals, it seems intuitive that children with lower SR are at greater risk of weight gain via the consumption of large meals. We know that children with lower SR tend to gain weight at a faster rate (van Jaarsveld et al. 2014; Mccarthy et al. 2015; Carnell & Wardle 2008; Webber et al. 2009; French et al. 2012) and indeed **Chapter 8** indicated that meal size partly mediated the association between satiety responsiveness and weight. Although the mediation effect was small, indicating that there may also be other behaviours or mechanisms through which children who are low on satiety sensitivity gain weight. Interestingly, while higher FR was associated with higher meal frequency, meal frequency was not associated with weight gain in **Chapter 7**, and therefore FR does not appear to be associated with weight via this particular mechanism at this age.

Chapters 4 to 8 highlighted that both the 'what' and the 'how' of children's eating may influence weight trajectories during early life. It is therefore important to explore whether these aspects of eating behaviour track during childhood. **Chapter 9** demonstrated that not only do energy and nutrient intakes show stability from early to mid-childhood, but consumption patterns (size and frequency of eating occasions), and appetitive characteristics also do. Children consuming higher intakes of energy and nutrients, or those who eat larger amounts and/or eat more often in early life, tend to continue to do so as they get older as well. Children do not seem to 'grow out of' the eating habits that are established in early life.

10.2 Implications for theory, practice and future research

There is now good evidence that on average, the diets of children in the UK contain more energy than recommended and contain excess protein and sodium. These findings have implications for weight gain and ill health, and highlight that parents may need more guidance and support on appropriate types, amounts and varieties of foods and drinks for toddlers. They may need more guidance on checking food labels, choosing lower fat and lower salt options, and limiting processed food. Dietary vitamin D intake is low among young children and there is a need to increase parental awareness of i) the recommendations for all children six months to five years of age to take a vitamin D supplement, and ii) food types that are fortified with vitamin D.

Findings also show that appetite plays a role in *what* young children eat and drink. Toddlers with a lack of interest in, and low intake of, food were given formula milks for an extended period of time, and whilst this did not appear to lead to excess energy intake or weight gain, the long-term implications on eating behaviours for example are unknown. Nevertheless, mothers of toddlers with poorer appetites should be offered more guidance on weaning and the introduction of solid food extending beyond 12 months.

Appetite was also shown to play a role in *how* young children eat and drink. Children with more avid appetites appear to be at risk of overconsumption; children who respond strongly to food cues eat more frequently, and children with lower sensitivity to satiety consume larger amounts each time they eat. The latter however appears to be a more critical pathway towards overweight, as meal size was found to be associated with weight gain, but meal frequency was not. In addition, meal size partly mediated the association between satiety responsiveness and weight. Knowledge of this dietary pathway is important for developing practical and targeted interventions to prevent excessive weight gain in children behaviorally susceptible to obesity. We know that satiety responsiveness is partly determined by genetic variation, which implies that overconsumption and subsequent weight gain is out of an individual's control; some children will find it more difficult than others to regulate their food intake because they have inherited a susceptibility to overeating. However, this does not mean that consumption patterns cannot be modified. Assessing appetitive traits in early childhood could help to identify children with lower satiety responsiveness. Parents of these children may benefit from feeding advice tailored to their child's appetite, for example how to enforce a 'no second helpings' policy. The main implication of these findings however is the importance of guidance on appropriate portion sizes for young children. Some children may be particularly susceptible to overeating in response to larger serving sizes and parents and carers of certain children may need to guard against 'over-serving', offering dessert, and encouraging 'plate clearing'. Parents need to be provided with information on feeding their children in a way which fosters healthier weight trajectories.

In addition to identifying dietary pathways that place some young children at greater risk of excess weight gain, this thesis has also demonstrated that appetite, dietary intake and consumption patterns track over time. It is therefore important to establish healthy eating practices early in life that will be maintained as children get older. Meal size in particular should be targeted in early life and there are a number of reasons for this. Firstly, we know that meal size in early life is linked to weight gain. Secondly, from early to mid-childhood children continue to eat approximately five times per day but their meal sizes become larger. While this is likely in part because they have higher energy requirements as they get older and heavier, if the increase in meal size with age is too great, it could lead to excess weight gain. Large serving sizes in early life may be shaping children's perceptions about what is an appropriate amount to eat. Finally, we know that children susceptible to consuming larger meals (those with lower satiety responsiveness) continue to have lower satiety responsiveness as they get older. As children begin to have more autonomy over food choices, it is important that parents provide a ‘healthy’ environment to minimise opportunities for the expression of appetitive traits that might result in excess weight gain. Without intervention in early life there are implications for the continuation of an overweight trajectory throughout childhood, adolescence and adulthood. However, in order to determine the long-term consequences of consumption patterns in early life, further research is needed into the appetites, consumption patterns and weight trajectories of children from early in life to later childhood and adolescence.

10.3 Strengths and limitations

10.3.1. Strengths

The studies in this thesis have a number of strengths, setting them apart from previous research. Appetite was assessed using a psychometrically valid measure; the CEBQ. A reliable method of estimating energy intake in children was also used; three day diet diaries, which have been validated against the doubly labelled water method (Lanigan et al. 2001). Within Gemini, parents were provided with portion guides and detailed instructions on recording food and drink intake which helps with standardisation. The largest contemporary dietary dataset for children aged 21 months in the UK has been used for much of this thesis, and in **Chapter 4** comparisons with the nationally representative NDNS sample showed great similarities, suggesting that despite being obtained from a twin sample, the dietary data within Gemini is a valuable resource.

Exploring dietary intake in very young children has been a great strength of this research. Parents of young children often do not perceive their children to be overweight (Syrad et al. 2014; Campbell et al. 2006), and as a result are potentially less likely to misreport their child’s intake (Livingstone et al. 2004). Also, research into adults is confounded by the possibility that they may be modifying their diet as a result of current weight status, for example skipping meals to lose weight (Woodruff et al. 2008; Boutelle et al. 2009). This is not an issue when exploring dietary intake in very young children, especially as intake here was parent-reported.

In **Chapter 5** both quantitative and qualitative methods were used to explore parental decision making during the complementary feeding period, and this helped to confirm hypotheses generated from the quantitative data analysis. The longitudinal nature of the Gemini study enabled the exploration of the role of dietary intake in weight gain over time in **Chapters 5 and 7**. Adjustments were made for earlier weight which offers more confidence that independent associations between diet and weight gain were established. In **Chapter 7**, associations between consumption patterns (meal size and frequency), and weight remained when over- and under-reporting was taken into account, suggesting that the dietary reports provided by parents throughout this thesis were valid. The findings were also replicated at a cross-sectional level in a large, nationally representative sample; the DNSIYC, suggesting the findings are generalizable to singletons and the wider population.

Health professional measured heights and weights were used for the first two years in the Gemini study and from two years onwards parents were supplied with weighing scales and height charts to ensure standardisation. Previous research has shown a high correlation between researcher- and parent-measured weight (Wardle et al. 2008) supporting the reliability of the measurements obtained.

Within this thesis I have collected, coded and analysed longitudinal diet diary data at two time points for the same sample of children, using the same assessment methods. No previous study has tracked consumption patterns (meal size and frequency) between two time points during childhood.

10.3.2 Limitations

There are weaknesses inherent in this research that must be acknowledged. Firstly, many of the studies have used cross-sectional data and this prevents conclusions being drawn about the direction of causation. For example, in **Chapter 5**, I cannot be sure whether poorer appetite and lower food intake stimulated parents to continue formula feeding, or formula milks suppressed appetite and subsequent food intake. However, qualitative data with mothers supported the former direction of causality; that parents fed formula in response to their child's lack of interest in food. Also, previous research has suggested that parents often feed in response to their child's appetitive traits. Carnell et al (2011) conducted a qualitative study in which they interviewed 22 mothers of predominantly healthy weight three to five year olds in the UK to explore feeding behaviours and underlying motivations. The most common theme to arise was that mothers fed in response to their child's appetitive traits and/or food preferences. They reported that they would limit access to less healthy foods if their child would eat excessive amounts, or if their child had a smaller appetite they would have to remind them to eat (Carnell et al. 2011).

The associations observed between meal size and concurrent weight and weight status in Gemini reported in **Chapter 7** were replicated in the DNSIYC sample. However, the replication was cross-sectional so it might be that heavier children in the DNSIYC consumed larger meals and subsequently more daily energy, because they required more energy. Similarly, in **Chapter 6** children with lower satiety responsiveness were found to consume larger meals and children who were more food responsive ate more often. However, rather than appetite driving intake, it could simply be that consuming larger meals overrides satiety sensitivity and disrupts children's ability to respond to satiety mechanisms; and that eating more frequently causes children to become more food responsive, through a process such as conditioning. Not only this but as parents reported on both appetitive traits and consumption patterns, they may simply be measuring the same underlying construct and may not be fully independent assessments. Longitudinal data are required to establish potential causal directions between appetitive traits and eating patterns.

Measurement error may have influenced findings within this thesis. The parent-reported heights and weights used throughout could have introduced error as parents are slightly less accurate at measuring than researchers (Wardle et al. 2008) and different parents may measure in different ways. However, all parents were supplied with the same weighing scales and height charts. There is also the possibility that parents may have under-reported their child's weight, however, parental under-reporting of weight for overweight children increases with age (Maynard et al. 2003; Akinbami & Ogden 2009; O'Connor & Gugenheim 2011) so it is less likely that under-reporting occurred during early childhood, although it might have occurred at seven years of age. That might in part explain the smaller proportion (12%) of overweight at seven years of age. Due to the cohort nature of the Gemini sample, parental compliance with returning weight and height measurements reduced over time so there was a reduced sample for analysis at five years of age.

The method used for dietary data collection is open to error as parents need to recollect the items of food and drinks consumed by their child. To try and overcome this parents were asked to complete the diaries prospectively and not from memory. There is also the possibility that parents reported the same entries for both children because it is less onerous than reporting the two separately. However, the analyses conducted throughout this thesis adjusted for the clustering of twins which meant that rather than using only one twin from each family at random, analyses included both children, increasing the sample size.

There were aspects of the sample that may have impacted on the research. Firstly, the Gemini sample is highly educated and consequently these parents may have greater knowledge of dietary recommendations resulting in the reporting of more favourable dietary intakes (Macdiarmid & Blundell 1998). At seven years of age the sample size was small (*n*= 200) and larger samples would increase the power to detect significant associations.

Information on energy expenditure was not collected in any of the samples used in this research so I have been unable to determine the entirely independent contribution of energy intake on growth.

There is currently no standard definition of an eating or drinking occasion (Gatenby 1997; Duval & Doucet 2012; Oltersdorf et al. 1999; Kerver et al. 2006) and it is possible that other definitions might have resulted in different findings. This highlights the need for consistent methods of eating occasion definitions in the literature (Duval & Doucet 2012; Oltersdorf et al. 1999; Kerver et al. 2006) and this is an area for further research.

10.4 Conclusions

The overall aim of this thesis was to identify behavioural pathways through which individual differences in appetite may result in weight gain. I have been able to demonstrate that appetite appears to play a role in *how* children eat, and subsequently influences weight gain during childhood. Previous research had identified that children with lower satiety responsiveness and higher food responsiveness consumed more food during experimental tasks, but this thesis sheds light on associations between these appetitive traits and consumption patterns within an everyday context. It therefore provides some ecological support for the behavioural susceptibility theory (Carnell & Wardle 2008) and highlights the dietary pathways through which appetitive traits might lead to excess weight gain. Children with lower satiety responsiveness consume larger meals, and those with higher food responsiveness eat more frequently. Meal size mediates the association between satiety responsiveness and weight, providing support for the Behavioural

Susceptibility Theory. Children with lower sensitivity to satiety are more likely to overeat in the current food environment, and subsequently gain excess weight. Meal frequency however does not seem to be the pathway through which young children with higher food responsiveness gain weight. Further research is necessary to understand the mechanisms through which food responsiveness places individuals at greater risk of excess weight gain.

The findings in this thesis have a number of implications for public health policy as well as clinical intervention. Appetitive characteristics appear to influence consumption behaviour which subsequently places some individuals at greater risk of weight gain. Whilst both FR and SR have a strong genetic basis, there is also an important environmental contribution; and these traits are expressed via eating behaviours (eating larger meals and eating more often) depending on environmental exposure. This opens up the possibility that environmental modification could help to prevent overconsumption for susceptible children. The UK government could perhaps enforce tighter regulation on aspects of the food environment that might promote overconsumption. For example if the government was to cap the number of television adverts that market energy dense or sugary foods and drinks to children, those who are responsive to food cues might eat less often. Similarly, this could be achieved if there were regulations surrounding the number and location of fast food venues, for example ensuring there are none within close proximity to schools so children are not passing them on their way home. There could also be regulations to ensure that supermarkets are not allowed to place chocolate bars and sweets at the till point. This in turn might help parents who struggle to say “no” if their child asks for food when they are queueing to pay for shopping. The enforcement of these regulations would involve multiple organisations to work together; not only the government but the food industry, the media and also academics to relay messages about the importance of modifying the environment.

This thesis has demonstrated that meal size drives weight gain during early life and this has implications for reducing portion sizes in restaurants, schools as well as in supermarkets; food companies could reduce the portion sizes of pre-packaged foods and drinks targeted at children. Arguably this may have some impact as children have been shown to eat more when served more (Rolls et al. 2000) and also to serve themselves more when they are given larger plates and bowls (Disantis et al. 2013). At a population level, health visitors have a role to play in guiding parents of young children; for example making them aware of healthy growth trajectories and what it means if a child starts crossing centiles on the growth charts, providing information on healthy foods, and also signposting to available information, for example via the Infant and Toddler Forum. However, while policy changes and strategies aimed at parents of all children may help with tackling weight gain at a population level, but this thesis has demonstrated that not all children are susceptible to overconsumption. Children consuming larger meal sizes gained most weight over time but guidance on appropriate portion sizes for children is currently lacking. While it is likely to be beneficial to offer advice on portion sizes for young children it is a complex and difficult proposition. The effect sizes are very small for the association between meal size and weight – making the corresponding differences in portion size almost undetectable to the naked human eye. Additionally children all grow at different rates and have different energy requirements. More research is needed into how to develop accurate portion guidelines for young children, and how to talk to parents about this issue. Children with lower satiety responsiveness appear to be most at risk of overeating (via large meal sizes) so may be particularly susceptible to larger serving sizes. More detailed guidance for parents, and especially those of children with lower satiety responsiveness, is needed on appropriate feeding practices that are likely to encourage healthy eating patterns. If parents have a child with lower satiety responsiveness, healthcare professionals could offer advice on how to guard against 'over-serving', for example by not serving children the same portions as they would serve themselves, and also how to avoid offering second helpings. Potential strategies that could be used by health care professionals when working with parents of children who have low satiety responsiveness are shown in **Table 10.1.** Children who are responsive to food cues have been shown to eat more often, and as children get older this has the potential to lead to overconsumption. Healthcare professionals could offer suggestions to parents such as putting palatable foods out of sight. Other potential strategies that could be used by health care professionals when working with parents of children who have high food responsiveness are shown in **Table 10.1.** Given the observational nature of the current thesis, the strategies suggested for potentially preventing overconsumption need to be tested with intervention studies, conducted early in life. Only then will we be able to establish how healthy eating practices can be developed during childhood.

Table 10.1 Feeding strategies for healthcare professionals when speaking to parents of children with 'avid' appetites

Satiety Responsiveness	Food Responsiveness
Serve smaller portions than served to adults	Do not have palatable foods on display
No second helpings	Have fruit and vegetables available
No desserts	Offer snacks with low energy density, e.g. carrot sticks
Do not encourage plate clearing	Provide three meals and two snacks
Eat meals at the table (no TV) to ensure a focus on feelings of fullness	Eat meals at the table (no TV) to avoid food adverts
Family meals	
Offer foods that impact on satiety e.g. porridge	
Encourage slower eating to allow time for the child to feel satiated	
Notice satiation cues during milk feeding, e.g. Turning head away	

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APPENDICES

CHAPTER 1

Appendix 1.1 The Dutch Eating Behaviour Questionnaire (DEBQ)

		Never	Seldom	Sometimes	Often	Very often
1	If you have put on weight, do you eat less than you usually do?					
2	Do you have the desire to eat when you are emotionally upset?					
3	Do you try to eat less at mealtimes than you would like to eat?					
4	If you have something delicious to eat, do you eat it straight away?					
5	Do you deliberately eat foods that are slimming?					
6	If food smells and looks good, do you eat more than usual?					
7	Do you have the desire to eat when you are approaching something unpleasant to happen?					
8	When you have eaten too much, do you eat less than usual the following days?					
9	Do you have the desire to eat when you are depressed or discouraged?					
10	If you see others eating, do you also have the desire to eat?					
11	Do you have the desire to eat when you are frightened?					
12	Do you take into account your weight with what you eat?					
13	Do you have the desire to eat when you are irritated?					
14	How often do you refuse food or drink offered because you are concerned about your weight?					
15	Do you have the desire to eat when you have nothing to do?					
16	When a meal is being prepared, are you inclined to eat something?					
17	Do you watch exactly what you eat?					
18	Do you have the desire to eat when you are feeling lonely?					
19	How often in the evening do you try not to eat because you are watching your weight?					
20	Do you have the desire to eat when you are cross?					
21	Do you deliberately eat less in order not to become heavier?					
22	Do you have the desire to eat when you are anxious, worried or tense?					
23	Can you resist eating delicious foods?					
24	How often do you try not to eat between meals because you are watching your weight?					
25	Do you have the desire to eat when you are bored or restless?					
26	If you walk past a snack bar or a cafe, do you have the desire to buy something delicious?					
27	Do you have the desire to eat when you are disappointed?					
28	If food tastes good to you, do you eat more than usual?					
29	Do you have the desire to eat when somebody lets you down?					
30	If you see others eating, do you also have the desire to eat?					
31	If you walk past the baker, do you have the desire to buy something delicious?					
32	Do you have the desire to eat when things are going against you or when things have gone wrong?					
33	If you see or smell something delicious, do you have a desire to eat it?					

Appendix 1.2 The Child Eating Behaviour Questionnaire (CEBQ)

ID:

Child Eating Behaviour Questionnaire (CEBQ)

Please read the following statements and tick the boxes most appropriate to your child's eating behaviour.

	Never	Rarely	Some-times	Often	Always
My child loves food	☐	☐	☐	☐	☐
My child eats more when worried	☐	☐	☐	☐	☐
My child has a big appetite	☐	☐	☐	☐	☐
My child finishes his/her meal quickly	☐	☐	☐	☐	☐
My child is interested in food	☐	☐	☐	☐	☐
My child is always asking for a drink	☐	☐	☐	☐	☐
My child refuses new foods at first	☐	☐	☐	☐	☐
My child eats slowly	☐	☐	☐	☐	☐
My child eats less when angry	☐	☐	☐	☐	☐
My child enjoys tasting new foods	☐	☐	☐	☐	☐
My child eats less when s/he is tired	☐	☐	☐	☐	☐
My child is always asking for food	☐	☐	☐	☐	☐
My child eats more when annoyed	☐	☐	☐	☐	☐
If allowed to, my child would eat too much	☐	☐	☐	☐	☐
My child eats more when anxious	☐	☐	☐	☐	☐
My child enjoys a wide variety of foods	☐	☐	☐	☐	☐
My child leaves food on his/her plate at the end of a meal	☐	☐	☐	☐	☐
My child takes more than 30 minutes to finish a meal	☐	☐	☐	☐	☐

	Never	Rarely	Some-times	Often	Always
Given the choice, my child would eat most of the time	☐	☐	☐	☐	☐
My child looks forward to mealtimes	☐	☐	☐	☐	☐
My child gets full before his/her meal is finished	☐	☐	☐	☐	☐
My child enjoys eating	☐	☐	☐	☐	☐
My child eats more when she is happy	☐	☐	☐	☐	☐
My child is difficult to please with meals	☐	☐	☐	☐	☐
My child eats less when upset	☐	☐	☐	☐	☐
My child gets full up easily	☐	☐	☐	☐	☐
My child eats more when s/he has nothing else to do	☐	☐	☐	☐	☐
Even if my child is full up s/he finds room to eat his/her favourite food	☐	☐	☐	☐	☐
If given the chance, my child would drink continuously throughout the day	☐	☐	☐	☐	☐
My child cannot eat a meal if s/he has had a snack just before	☐	☐	☐	☐	☐
If given the chance, my child would always be having a drink	☐	☐	☐	☐	☐
My child is interested in tasting food s/he hasn't tasted before	☐	☐	☐	☐	☐
My child decides that s/he doesn't like a food, even without tasting it	☐	☐	☐	☐	☐
If given the chance, my child would always have food in his/her mouth	☐	☐	☐	☐	☐
My child eats more and more slowly during the course of a meal	☐	☐	☐	☐	☐

Appendix 1.3 The Child Eating Behaviour Questionnaire – Toddler (CEBQ-T)

CHILDREN'S EATING BEHAVIOUR QUESTIONNAIRE FOR TODDLERS (CEBQ-T)

How would you describe your child's eating styles on a typical day?

	Never	Rarely	Sometimes	Often	Always
1. My child loves food	☐	☐	☐	☐	☐
2. My child eats more when irritable	☐	☐	☐	☐	☐
3. My child has a big appetite*	☐	☐	☐	☐	☐
4. My child finishes his/her meal quickly*	☐	☐	☐	☐	☐
5. My child is interested in food	☐	☐	☐	☐	☐
6. My child cannot eat a meal if he/she has had a snack just before	☐	☐	☐	☐	☐
7. My child refuses new foods at first	☐	☐	☐	☐	☐
8. My child eats slowly	☐	☐	☐	☐	☐
9. My child looks forward to mealtimes	☐	☐	☐	☐	☐
10. My child is always asking for food	☐	☐	☐	☐	☐
11. My child eats more when grumpy	☐	☐	☐	☐	☐
12. If allowed to, my child would eat too much	☐	☐	☐	☐	☐
13. My child eats more when upset	☐	☐	☐	☐	☐
14. My child enjoys a wide variety of foods*	☐	☐	☐	☐	☐

	Never	Rarely	Sometimes	Often	Always
15. My child leaves food on his/her plate or in the jar at the end of a meal	☐	☐	☐	☐	☐
	Never	**Rarely**	**Sometimes**	**Often**	**Always**
16. My child takes more than 30 minutes to finish a meal	☐	☐	☐	☐	☐
17. Given the choice, my child would eat most of the time	☐	☐	☐	☐	☐
18. My child enjoys tasting new foods*	☐	☐	☐	☐	☐
19. My child gets full before his/her meal is finished	☐	☐	☐	☐	☐
20. My child enjoys eating	☐	☐	☐	☐	☐
21. My child is difficult to please with meals	☐	☐	☐	☐	☐
22. My child decides that he/she does not like a food, even without tasting it	☐	☐	☐	☐	☐
23. My child eats more and more slowly during the course of a meal	☐	☐	☐	☐	☐
24. Even when my child has just eaten well, he/she is happy to eat again if offered	☐	☐	☐	☐	☐
25. My child gets full up easily	☐	☐	☐	☐	☐
26. My child is interested in tasting food he/she has not tasted before*	☐	☐	☐	☐	☐

Appendix 1.4. Summary of studies exploring the relationship between appetite and meal patterns in children

Author & year	Sample characteristics					Measure of Appetite	Meal pattern	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity** (n)	**Weight status**				
(Carnell & Wardle 2007)	111	4-5 years	F=50.0 M=50.0	UK W =82 NW=29	N/A	CEBQ	EI during a meal, following a preload, and during EAH task	CS-EXP	SR was associated with lower energy intake during the lunch meal, in the EAH task, and following a preload. Higher scores on FR were associated with greater energy intake at the lunch meal, but were not associated with EAH or energy compensation.
(Mallan et al. 2014)	37	2 years followed up at 4 years	F=56.8 M=43.2	Australia	HW =94.6 OW =5.4	CEBQ	EAH task – EI during lunch and ab libitum intake of snacks	LG-EXP	Children scoring lower on SR at 2 years consumed more energy during the lunch meal at 4 years than those scoring higher. No association between SR and intake of snacks, or between FR and either intake at the meal or snacks.

Author & year	Sample characteristics					Measure of Appetite	Meal pattern	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity** (n)	**Weight status**				
(Mehra et al. 2011)	35	6-10 years	F=54.3 M=45.7	US W =30 NW= 5	HW =51.4 OW =48.6	Visual analogue scale of fullness	Eating frequency and meal size (kJ consumed) of test meals and ab libitum intake.	CS-EXP On two separate days children were randomly assigned to one of two meal patterns (five or three meals), equal in energy content. They were then offered ice cream (1,2,3 or 4 scoops) twice. Children indicated their fullness after each meal and after each ice cream offering. Energy intake was measured after each meal and ice-cream session.	Fullness ratings did not differ by meal pattern either prior to, or after, the icecream. Ice-cream consumption. However ice-cream consumption (kJ) was negatively associated with fullness ratings – greater consumption among those who rated themselves less full after the meal patterns, regardless of whether they consumed three or five meals.

Author & year	Sample characteristics					Measure of Appetite	Meal pattern	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity** (n)	**Weight status**				
(Mooreville et al. 2015)	100	5-6 years	F= 55 M= 45	US Non-hispanic black	HW =66 OW =34	CEBQ	Meal size (kJ consumed) across four test meals varying in portion size (2833, 4247, 5661 and 7075 kJ)	CS-EXP Over four weekly visits, children were given free access to a meal which varied in portion size on each visit. Energy consumed on each meal was measured.	A main effect of SR on meal size was found – children with lower SR consumed more energy during each meal. No main effect was found between meal size and FR. An interaction effect was also observed - as portion sizes increased, children with greater FR consumed more energy, and children with lower SR consumed more energy.

F, females; M, males; W, white; NW, non-white; HW, Healthy weight; OW, Overweight; N/A, Information not available; CEBQ, Child Eating Behaviour Questionnaire; EI, energy intake; EAH, Eating in the Absence of Hunger; CS-EXP, cross-sectional experimental study; SR, Satiety Responsiveness; FR, Food Responsiveness; LG-EXP, longitudinal experimental study; kJ, kilojoules

Appendix 1.5 Summary of studies exploring the relationship between meal frequency and weight in children

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Antonogeorgos et al. 2012)	700	10-12 years	F=53.9 M=46.1	Greece	OW=36.6 HW=63.4	FFQ: “How many meals per day does your child usually consume? (Response options: 1,2,3 >3 per day)	Weight status classified using IOTF classifications based on adult cut-offs (OW BMI≥25 kg/m²) and obesity (≥30 kg/m²) adjusted for age and sex.	CS	No association between EF and weight status. Significant interaction between EF and breakfast consumption - children consuming >3 meals per day and not skipping breakfast were 2x less likely to be OW
(Barba et al. 2006)	3668	6-11 years	F=50.0 M=50.0	Italy	N/A	FFQ: Daily eating frequency (meals/snacks) (≤3, 4, ≥5 per day)	BMI and WC	CS	Significant negative association between EF and both BMI and WC – as meal frequency increased BMI and WC decreased.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%**)				
(Beyerlein et al. 2008)	4967	4.5 – 7.3 years	F=48.0 M=52.0	Germany	N/A	FFQ: daily meal frequency (≤3, 4, ≥5 per day)	BMI	CS	EF was negatively associated with BMI.
(Bo et al. 2014)	400	11-13 years	F=48.0 M=52.0	Italy	OW= 16.5 HW= 83.5	FFQ: number of snacks per day (1,2, ≥3)	BMI and weight status (OW BMI≥85th centile according to Italian growth charts)	CS	Prevalence of overweight was significantly higher in children consuming ≥3 snacks per day.
(Cassimos et al. 2011)	335	11 years	F=46.0 M=54.0	Greece	Obese=15.8 OW=33.7 HW=51.4	FFQ (≤3 or >3 meals per day)	Weight status classified using IOTF classifications adjusted for age and sex.	CS	Obese children had ≤3 meals per day in a significantly increased proportion compared to OW or HW children.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Coppinger et al. 2012)	264	10-13 years	F=50.4 M=49.6	UK	Obese=4.0 OW=13.0 HW=76.0 UW=7.0	3 day diary: number of eating occasions per day	BMI	CS	No association between EF and BMI
(Eloranta et al. 2014)	408	6-8 years	F=51.2 M=48.8	Finland	OW=11.8 HW=88.2	4 day diaries: <3 or ≥3 meals per day	WC	CS	EF was negatively associated with WC: children consuming less than 3 meals per day more likely to be overweight.
(Fábry et al. 1966)	226	6-16 years	N/A	Czech	N/A	Three schools differed in the number of meals served to children (3, 5 or 7 per day)	Weight and skinfold thickness	CS	Children consuming 3 meals per day were heavier and had greater skinfold thickness than those consuming 5 or 7 meals.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Farajian et al. 2014)	4552	10-12 years	F=51.2 M=48.8	Greece	OW=42.2 HW=58.8	FFQ – self report Number of meals and snacks per day	Weight status classified using IOTF classifications adjusted for age and sex.	CS	Significant positive association between EF and OW.
(Ferreira & Marques-Vidal 2008)	1125	6-10 years	F=48.4 M=51.6	Portugal	OW=35.6 HW=64.4	FFQ- number of meals per day	Weight status classified using IOTF classifications adjusted for age and sex.	CS	No association between EF and OW status

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Francis et al. 2003)	173	5 years (followed up at 7 and 9 years)	F=100 M=0	US	5 years OW=26.0 HW=74.0 7 years OW=26.0 HW=74.0 9 years OW=41.0 HW=59.0	3 x 24 hour dietary recalls: snacking frequency	Increase in BMI between 5 to 9 years. Weight status classified using IOTF classifications based on adult cut-offs (OW BMI ≥25 kg/m²) and obesity (≥30 kg/m²) adjusted for age and sex.	LG	No significant association between EF aged 5 years and BMI change from 5 to 9 years.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Franko et al. 2008)	2379	9 years (followed up to 19 years)	F=100 M=0	US	N/A	3 day food diaries: dietician coded meals and snacks	BMI-for-age z-scores and weight status defined using CDC guidelines (≥95th percentile)	L G	Children eating >3 meals per day at 9 years had lower BMI-for-age z-scores and lower increases in BMI up to age 19 years. No association between meal frequency and weight status
(Huang et al. 2004)	1995	3-5 years (*n*= 1077) 6-11 years (*n*= 537) 12-19 years (*n*= 381)	F=49.6 M=50.4 F=49.6 M=50.4 F=49.6 M=50.4	US	3-5 years: HW=745 OW=332 6-11 years HW=459 OW=78 12-19 years HW=346 OW=35	Two day food diaries : daily eating frequency and snacking frequency	BMI percentile (<85th or ≥85th)	CS	Total eating frequency was negatively associated with BMI percentile in boys 12-19 years but not associated with BMI in any other age group or in girls. Snacking frequency was negatively associated with BMI percentile in girls 6-11 years but no other age group or among boys.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Jääskeläinen et al. 2013)	6247	16 years	F=50.9 M=49.1	Finland	OW=14.8 HW=85.2	FFQ – number of meals per day (5, ≤4 including breakfast, ≤4 not including breakfast)	WC and weight status classified using IOTF classifications (OW BMI ≥25 kg/m²) and obesity (≥30 kg/m²) adjusted for age and sex.	CS	Five meals per day (3 meals + 2 snacks) was associated with reduced risk of OW and abdominal obesity.
(Jennings et al. 2012)	1700	9-10 years	F=56.0 M=44.0	UK	OW=39.2 HW=61.8	4 day diaries – number of eating occasions per day	Weight, BMI, BMI z-score, WC and weight status, defined using waist to hip ratio (OW >0.46 boys, >0.45 girls)	CS	No difference in EF between OW and HW children. In HW children, increased EF was inversely associated with weight, BMI, BMI z-score and WC. In obese children, each increase in eating occasion was positively associated with BMI z-score and waist-to- height ratio.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Keast et al. 2010)	5811	12-18 years	F=48.9 M=51.1	US	OW=32.3 HW=67.7	24 hour recall: frequency of snacks (0,1,2,3, ≥4 per day)	BMI, BMI percentile, WC, weight status classified using CDC reference data. BMI-for-age percentile <85th (HW) or ≥85th (OW)	CS	Negative association between EF and BMI, BMI percentile, WC. Children consuming more snacks were less likely to be OW
(Kontogianni et al. 2010)	1170	3-12 years (*n*= 653)	F=47.6 M=52.4	Greece	Obese=12.9 OW=18.2 HW=55.8	24 hour recall: number of eating episodes per day	Weight status classified using IOTF classifications adjusted for age and sex.	CS	No association between eating frequency and weight status among 3-12 years nor 13-18 years
		13-18 years (*n*= 517)	F=53.8 M=46.2		Obese=2.8 OW=13.5 HW=76.9				

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Kosti et al. 2007)	2008	12-17 years	F=49.2 M=50.8	Greece	OW=19.3 HW=80.7	FFQ – daily eating episodes (meals and snacks) per day grouped into ≥3 or <3	Weight status classified using IOTF classifications adjusted for age and sex.	CS	Increased number of eating episodes inversely associated with likelihood of OW in boys, but not girls
(Lagiou & Parava 2008)	633	10-12 years	F=50.0 M=50.0	Greece	OW=19.3 HW=80.7	FFQ – number of daily eating episodes	Weight status defined using Greek growth reference curves (OW ≥85th percentile)	CS	With adjustment for daily energy intake, children consuming more frequent meals had significantly lower prevalence of obesity
(Lioret et al. 2008)	748	3-11 years	N/A	France	OW=16.4 HW=83.6	7 day food diary: number of eating occasions per day	Weight status classified using IOTF classifications adjusted for age and sex.	CS	EF was inversely associated with odds of OW

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Maffeis et al. 2008)	1837	8-10 years	F=49.7 M=50.3	Italy	Obese=5.0 OW=21.1 HW=73.9	FFQ- number of snacks per day	Weight status classified using IOTF classifications adjusted for age and sex.	CS	No significant difference between OW and HW in number of snacks per day
(McConahy et al. 2002)	899	1 year	N/A	US	UW=84 HW=651 OW=164	Two day food diaries: Number of eating occasions (food and drink) per day.	Weight status classified as BMI-for-age percentile <15th (UW), 15th-85th (HW) or ≥85th (OW)	CS	No differences across percentiles of body weight in the number of eating occasions per day.
(Mota et al. 2008)	886	13-17 years	F=48.0 M=52.0	Portugal	OW=20.3 HW=79.7	FFQ: daily meal frequency (response options: 1,2,3,4,5,6 which were then grouped into (≤3 or 4, ≥5 per day)	Weight status classified using IOTF classifications adjusted for age and sex.	CS	Children consuming <3 meals per day more likely to be OW.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Murakami & Livingstone 2014)	1636	4-10 years (*n*= 818) 11-18 years (*n*= 818)	F=46.8 M=53.2 F=51.3 M=48.7	UK	N/A	7 day weighed food diary: number of eating occasions per day (food and drink) >210Kj	BMI z-scores	CS	EF inversely associated with BMI z-score in 11-18 year olds but not 4-10 year olds.
(Kentaro Murakami & Livingstone 2015)	1636	4-10 years (*n*= 818) 11-18 years (*n*= 818)	F=46.8 M=53.2 F=51.3 M=48.7	UK	N/A	7 day weighed food diary Two definitions: 1) meal = eating episode ≥15% of total EI 2) meals were defined by time of day 06.00–10.00, 12.00–15.00 and 18.00–21.00 hours. All other occasions were snacks.	BMI z-scores. WC and waist to hi[p ratio were calculated for 11-18 years	CS	No association between snack or meal frequency (using either definition) and BMI z-score in either age group. No association with WC in 11-18 years.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Neutzling et al. 2003)	528	15-19 years	F=43.2 M=56.8	Brazil	OW=50.0 HW=50.0	FFQ: number of daily meals	Weight status defined using NCSH reference data: OW= BMI ≥95th percentile, HW <95th percentile.	CS	Inverse association between >3 meals per day and OW
(Nicklas et al. 2003)	1562	10 years	F=50.7 M=49.3	US	OW=76.0 HW=24.0	24 hour dietary recall: total eating episodes (meals and snacks) per day	Weight status classified using CDC reference data. BMI-for-age percentile <85th (HW) or ≥85th (OW)	CS	Eating frequency was not associated with OW status
(Preston & Rodriguez-Quintana 2015)	331	11 years (*n*= 101) 13 years (*n*= 111) 16 years (*n*= 105)	F=61.4 M=38.6 F=58.3 M=41.7 F=59.0 M=41.0	Puerto Rico	OW=41 HW=59 OW=31 HW=69 OW=31 HW=69	24 hour dietary recall: number of eating occasions per day	Weight status classified using CDC reference data.	CS	Inverse association between number of eating occasions and weight status: healthy weight children consumed more meals per day among all age groups

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Ritchie 2012)	2372	9-10 years (followed up to 19-20 years)	F=100 M=0	US	N/A	3 day food diary: number of meals (≥15% of total EI), snacks, and total eating occasions (1-3, 3-4, 4-6, >6)	10 year change in BMI and WC	LG	Lower EF at 9-10 years was associated with greater 10-year increases in BMI and WC.
(Toschke et al. 2005)	4370	5-6 years	F=47.4 M=52.6	Germany	OW=12.9 HW=87.1	FFQ: How many meals per day does your child consume? (Response options: 1/2/3/4/5/>5 grouped into ≤3, 4 or ≥5 per day)	Weight status classified using IOTF classifications adjusted for age and sex.	CS	Inverse association between OW and EF
(Toschke et al. 2009)	4642	5-6 years	F=51.4 M=48.6	Germany	OW=4.0 NHW=96.0	FFQ: meals per day (1/2/3/4/5/>5, grouped into ≤3, 4 or ≥5 per day))	Weight status classified using IOTF classifications adjusted for age and sex.	CS	Obesity was inversely associated with EF

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Turkkahraman et al. 2006)	2645	6-17 years	F=50.0 M=50.0	Turkey	OW=17.9 HW=82.1	FFQ: number of meals (excluding snacks) per day. Grouped in 2, 3 or ≥4 per day.	Weight status classified using IOTF classifications based on adult cut-offs (OW BMI ≥25 kg/m²) and obesity (≥30 kg/m²) adjusted for age and sex.	CS	Lowest prevalence of OW in children consuming ≥4 meals per day, highest prevalence of OQ in children consuming 2 meals per day. Significant linear association between obesity and meal frequency
(Vik et al. 2013)	7915	10-12 years	F=52.1 M=47.9	Belgium, Greece, Hungary, the Netherlands, Norway, Slovenia, Spain, Switzerland	OW=24.8 HW=75.2	FFQ: "Did you eat breakfast/lunch/dinner yester- day?" (Response: yes/no, grouped into 0-1, 2 or 3 meals per day)	Weight status classified using IOTF classifications based on adult cut-offs (OW BMI ≥25 kg/m²) and obesity (≥30 kg/m²) adjusted for age and sex.	CS	Children consuming all three main meals had lower odds of being OW compared to HW than those consuming 0-1 or 2 meals.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Würbach et al. 2009)	2054	7-14 years	F=47.9 M=52.1	Germany	OW=9.7 HW=90.3	FFQ: Meal frequency (2,3,4,5).	BMI-SDS and weight status classified using German reference values: BMI ≤90th percentile; and overweight >90th percentile.	CS	Significant inverse association between BMI –SDS and EF.
(Zerva et al. 2007)	151	9-11 years	F=52.3 M=43.7	Greece	N/A	3 day food diaries: number of eating episodes (meals and snacks) per day. Grouped into tertiles (upper >5.5, mid 4.2-5.4, lower ≤4.1 eating occasions per day.	Sum of skinfolds, % body fat, and weight status defined using IOTF classifications adjusted for age and sex.		EF inversely associated with sum of skinfolds, and % body fat. Frequent eaters had lower central and total adiposity.

Author & year	Sample characteristics					Measure of meal frequency	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality /Ethnicity**	**Weight status (%)**				
(Zhang et al. 2009)	501 (258/ 243)	6-11 months	F=51.5 M=48.5	China	N/A	24hr dietary recall used to create an 'Infant and Child Feeding Index'. Meal frequency was defined using a points system Meal frequency (0/1/≥2) and snack frequency (0-1/≥2)	LAZ, WAZ and WLZ	CS	Meal frequency index was positively associated with infants' anthropometric indices (WAZ and WLZ). No association with LAZ.

F, females; M, males; W, white; NW, non-white; UW, Under weight; HW, Healthy weight; OW, Overweight; BMI, Body Mass Index; WC, Waist Circumference; FFQ, Food Frequency Questionnaire, IOTF, International Obesity Taskforce; EF, eating frequency; N/A, Information not availableble; CS, Cross-sectional study; LG, Longitudinal study; CDC, Centers for Disease Control; EI, energy intake; SDS, Standard Deviation Score; NCHS, National Center for Health Statistics; %, percentage; LAZ, length-for-age Z score; WAZ, weight-for-age Z score; WLZ, weight-for-length Z score

Appendix 1.6 Summary of studies exploring the relationship between meal size and weight in children

Author & year	Sample characteristics					Measure of meal size	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality**	**Weight status** (%)				
(Albar et al. 2014)	636	11-18 years	F= 48.4 M=51.6	UK	HW=65.7 OW=34.3	Four day food diaries: Portion size (grams) (weight/frequency) consumed of 20 energy dense food groups (e.g. nuts, chocolate, pizza).	BMI	CS	Positive association between BMI and portion size of food and drinks with high energy density.
(Bau et al. 2011)	1519	11-14 years	F=100	Berlin	UW=7.4 HW=81.1 OW=11.5	FFQ: Daily portion size score for 15 food groups usually consumed (1 portion = 1 handful). Portion sizes coded as optimal, normal or unfavourable.	Weight status using WHO classifications: UW<18kg/m² HW= 18-24.9kg/m² OW>24.9kg/m	CS	Weight status was not associated with portion size scores.

Author & year	Sample characteristics					Measure of meal size	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality**	**Weight status** (%)				
(Colapinto et al. 2007)	4966	10-11 years	F=51.1 M=48.9	Canada	N/A	Children indicated the portion size they usually consumed for 4 food common food items (French fries, meats, cooked vegetables and potato chips) Portion sizes (grams) were referenced against Canadian and American Guidelines for appropriate portions and categorised as less than or equal to the reference portion size.	Weight status classified using IOTF classifications based on adult cut-offs (OW BMI≥25 kg/m²) and obesity (≥30 kg/m²) adjusted for age and sex.	CS	No association between probability of overweight and portion sizes of any of the four food items.

Author & year	Sample characteristics					Measure of meal size	Measure of weight	Design	Findings
	n	Age	Sex (%)	Nationality	Weight status (%)				
(Huang et al. 2004)	1995	3-5 years (*n*= 1077) 6-11 years (*n*= 537) 12-19 years (*n*= 381)	F=49.6 M=50.4 F=49.6 M=50.4 F=49.6 M=50.4	US	3-5 years HW=69.1 OW=30.9 6-11 years HW=459 OW=78 12-19 years HW=85.5 OW=14.5	Two day food diaries: Portion size of meals and snacks consumed (grams and kJ)	BMI percentile (<85th or ≥85th)	CS	Meal size was positively associated with BMI percentile in children 12-19 years, and boys 6-11yrs. No associations for children 3-5 years, or girls 6-11 years.
(Kral et al. 2014)	50	8-10 years	F=52 M=48	US	HW=50 OW=50	Portion size consumed (kJ) when presented with meals varying in portion size (100%, 150%, 200%).	Weight status classified as BMI-for-age percentile <85th (HW) or ≥85th (OW)	CS	OW children consumed significantly more kJ compared to HW children in all three portion size conditions.

Author & year	Sample characteristics					Measure of meal size	Measure of weight	Design	Findings
	n	**Age**	**Sex** (%)	**Nationality**	**Weight status** (%)				
(Lin et al. 2013)	1138	3–7 years	F=47.6 M=52.4	China	HW=79.3 OW=20.7	Teacher observation: Portion size consumed (kJ) during lunch.	Weight status classified as BMI-for-age percentile <85th (HW) or ≥85th (OW)	CS	Children consuming larger meals were significantly more likely to be overweight
(Lioret et al. 2009)	748	3-6 years (*n*= 340) 7-11 years (*n*= 408)	F=45.6 M=54.4 F=49.4 M=51.6	France	HW=83.8 OW=16.2 HW=82.6 OW=17.4	Seven day food and drink diary: Portion sizes (grams and energy density) of food groups consumed (e.g. sweet or savoury snacks, cereals, cheese)	Weight status classified using IOTF classifications adjusted for age and sex.	CS	Among 3-6 year olds portion size of sweetened pastries was positively associated with OW. Among 7-11 years, portion size of liquid dairy products was positively associated with OW.

Author & year	Sample characteristics					Measure of meal size	Measure of weight	Design	Findings
	n	Age	Sex (%)	Nationality	Weight status (%)				
(McConahy et al. 2002)	899	1 year	N/A	US	UW=9.3 HW=72.4 OW=18.3	Two day food diaries: Portion size (grams) consumed per eating occasion.	Weight status classified as BMI-for-age percentile <15th (UW), 15th-85th (HW) or ≥85th (OW)	CS	Portion sizes were positively associated with body weight.
(Mooreville et al. 2015)	100	5-6 years	F=55 M=45	US	HW=66 OW=34	Meal size (kJ) consumed across four meals varying in portion size (2833, 4247, 5661 and 7075 kJ)	Weight status classified using CDC reference data. BMI-for-age percentile <85th (HW) or ≥85th (OW)	CS	No association between meal sizes consumed and weight status.

Author & year	**Sample characteristics**					**Measure of meal size**	**Measure of weight**	**Design**	**Findings**
	n	**Age**	**Sex** (%)	**Nationality**	**Weight status** (%)				
(Savage, Fisher, et al. 2012)	17	3-6 years	F=59 M=41	US	HW=64.7 OW=35.3	Meal size consumed (kJ) across six meals varying in portion size (100, 160, 220, 280, 340, 400 grams)	Weight status classified using CDC reference data. BMI-for-age percentile <85th (HW) or ≥85th (OW)	CS	OW showed significantly greater increases than HW children in kJ intake as portion sizes increased.

F, females; M, males; W, white; NW, non-white; UW, Under weight; HW, Healthy weight; OW, Overweight; BMI, Body Mass Index; WC, Waist Circumference; IOTF, International Obesity Taskforce; kJ, kilojoules; CDC, Centers for Disease Control; CS, Cross-sectional study;

CHAPTER 3

Appendix 3.1 Gemini initial invitation letter

gemini
health and development in twins

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

WELCOME TO GEMINI

Thank you for showing interest in our exciting new study: Gemini - which we are launching at UCL (University College London). You recently send a reply card back to the Office of National Statistics stating your interest in participating in this research. We are pleased to welcome you into Gemini.

Within the next few weeks, we are sending out the first questionnaires. We can also offer a web-based version if that is easy for you.

If you would like to fill out our web-based questionnaires we can send you the link by email. Please send us an email with your full name and postcode at Gemini@public-health.ucl.ac.uk indicating that you would like to receive the Gemini link and fill out questionnaires online.

If you prefer paper copies of questionnaires then you do not need to contact us; we will send you paper questionnaires and a pre-paid envelope (no stamp required) for easy return within the next few weeks.

If you have any queries about the study, please contact the Gemini team (Rebecca, Ellen, Clare or Laura) at 020 7679 6643 or send us an email at Gemini@public-health.ucl.ac.uk .

Kind regards,

Jane Wardle

Professor Jane Wardle

Appendix 3.2 Baseline questionnaire letter

gemini
health and development in twins

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

Dear <<Name Mother>> Family ID Number: GEM<<FAM ID>>

Thank you for indicating your interest in our exciting new study: Gemini – health and development in twins. You recently sent a reply card back to the Office of National Statistics stating that you would like to participate in this research. We are pleased to welcome you into Gemini.

Together with this letter you will find two copies of the consent form. To confirm your interest in Gemini, we would like to ask you to initial all the boxes on the consent form and sign them, and send one copy back to us together with the questionnaires and keep one copy for yourself.

Questionnaires
We have divided our questions in to two booklets for your convenience. The questionnaires are about your twins' growth, eating and activity habits and your views on feeding. The questionnaires also include some questions about various aspects of your home and family life. The information you provide will remain completely confidential. The questionnaires shouldn't take very long to complete and are designed to allow you to answer questions section by section at your own leisure.

Can I fill out the questionnaires online?
Yes, the questionnaires are available on the internet. If you would like to fill out our web-based questionnaires instead of the paper-based ones, please go to the following webpage, and follow the instructions: http://www.attitudestohealth.co.uk/gemini/
Please note that questions are divided into two parts just like the paper-based questionnaires. Each part needs to be completed in one go; although it is possible to take short breaks (15 minutes) as long as you leave the web browser open. Once you have started part one you will not be able to save it and come back to it later. However, after completing part one you can come back and complete part two (in one go) at your convenience.

What do I need to send back?
After you have signed the consent form and answered all of the questions in the two booklets, you can send us the consent form and both booklets in the freepost envelope (no stamps required). If you completed the questionnaires online, then just send the signed consent form in the freepost envelope to: Gemini, Health Behaviour Research Centre, UCL, 2-16 Torrington Place, London WC1E 6BT.

When will I be contacted again?
We would like to contact you again when the twins are about 15 months old. You do not have to let us know now whether or not you would like to continue to participate. We will confirm this with you the next time we contact you.

If you have any queries about the study, please contact the Gemini team (Rebecca, Ellen, Clare or Laura) at 020 7679 6643 or send us an email at Gemini@public-health.ucl.ac.uk.

Kind regards,

Jane Wardle

Professor Jane Wardle

Appendix 3.3 Baseline questionnaire

Family ID Number □□□□□□

WELCOME TO

gemini

health and development in twins

Booklet 1 - You and Your Family

Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
2-16 Torrington Place
London, WC1E 6BT
Gemini@public-health.ucl.ac.uk

HOW TO FILL IN THIS BOOKLET

Thank you for agreeing to fill out this booklet. Before you start, here is a bit of guidance:

- We realise that parents of twins are very busy! We are especially grateful.
- We know the questionnaire is quite long, but please try to answer *all* the questions you are asked. This will help us to get a full picture of you and your twins' circumstances.
- Please be as honest as you can when answering our questions. We want to know what you really think. Everything you tell us will be kept strictly confidential.
- This may sound obvious, but please write as clearly as possible. This will help us use all the valuable information you have provided.

<u>Here is an example of how a question *could* be answered.</u>

Most of the questions in this booklet will ask you to tick a box next to the answer that is most suitable. Some will also ask you to describe this answer in more detail, for example:

A1.	**Do you think your twins are identical or non-identical?**	Identical	☑	Non-identical	☐
	Why do you think this?	...The twins shared the same sac and placenta...			
A2.	**As your twins grow older, do you have more time for yourself?**	Yes	☑	No	☐

THIS QUESTIONNAIRE IS TO BE COMPLETED BY THE <u>MOTHER</u> OF THE TWINS.
IF YOU ARE NOT THE MOTHER, PLEASE CONTACT US AND WE WILL SEND YOU THE APPROPRIATE QUESTIONNAIRE

THANK YOU FOR YOUR TIME AND ASSISTANCE IN FILLING OUT THIS BOOKLET

2

YOUR TWINS

A1. Are you the primary caregiver of the twins? Yes ☐ No ☐

A2. What is your first born twin's name? ______________________

Is your first born twin a boy or a girl? Boy ☐ Girl ☐

What is his/her date of birth? ____/____/______
DD MM YYYY

A3. What is your second born twin's name? ______________________

Is your second born twin a boy or a girl? Boy ☐ Girl ☐

The next few questions are all about whether your twins are identical or non-identical. This section needs to be completed only if you have same sex twins (please note: non-identical twins are often called fraternal twins)

If your twins are opposite sex, please go straight to B1 on page 6

A4. Have you ever been told by a health professional (e.g. doctor, nurse, consultant) that your twins are identical or non-identical?

Yes, identical ☐ Yes, non-identical ☐ No ☐

If YES, why did they think this?______________________

____

A5. Do you think your twins are identical or non- identical?

Identical ☐ Non-identical ☐

Why do you think this is?

____

3

A6. **As your twins have grown older, has the likeness between them:**

Become less ☐ Remained the same ☐ Become more ☐

A7. **When looking at the twins:**

	None	Only slight difference	Clear difference
Are there differences in the shade of your twins' hair?	☐	☐	☐
Are there differences in the texture of your twins' hair (fine or coarse, straight or curly etc)?	☐	☐	☐
Are there differences in the colour of your twins' eyes?	☐	☐	☐
Are there differences in the shape of your twins' ear lobes?	☐	☐	☐

A8. **Have either of your twins' teeth begun to come through?** Yes ☐ No ☐

If yes, was it at about the same time?

Yes, the twins had matching teeth on the same side come through within a few days of each other ☐

Yes, the twins had matching teeth on opposite sides come through within a few days of each other ☐

Yes, the twins had different teeth come through within a few days of each other ☐

No, the twins' first teeth did not come through within a few days of each other ☐

A9. **Do you know your twins' ABO blood group and Rhesus (Rh) factors?**

Yes ☐ No ☐

If YES, what are they? (please tick a blood group and rhesus factor for each twin)

	Blood group: A	B	AB	O	Rhesus factor: Rh+	Rh-
1st born	☐	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐	☐

A10. When looking at a new photograph of your twins, can you tell them apart (without looking at their clothes or using any other clues)?

Yes, easily	Yes, but it is hard sometimes	No, I often confuse them in photographs
☐	☐	☐

A11. Do any of the following people ever mistake your twins for each other?

	Yes, often	Yes, sometimes	Rarely or never	Not applicable
Your partner / husband	☐	☐	☐	☐
Older brothers or sisters	☐	☐	☐	☐
Other relatives	☐	☐	☐	☐
Babysitter or day carer	☐	☐	☐	☐
Close friends	☐	☐	☐	☐
Casual friends	☐	☐	☐	☐
People meeting the twins for the first time	☐	☐	☐	☐

A12. If the twins are ever mistaken for one another, does this ever happen when they are together?

Yes, often	Yes, sometimes	No, almost never	They are not mistaken for one another
☐	☐	☐	☐

A13. Would you say that your twins:

Are as physically alike as "two peas in a pod" (virtually the same)	☐
Are as physically alike as brothers and sisters are	☐
Do not look very much alike at all	☐

ABOUT YOU

B1. What is your date of birth? ____ / ____ / ______ (DD / MM / YYYY)

B2. In general, would you say your own health is:

Excellent	Very good	Good	Fair	Poor
☐	☐	☐	☐	☐

B3. About how tall are you?

_____ centimetres (cms) OR _____ feet (ft) and _____ inches

B4. About how much do you weigh? If possible, use weighing scales for current weights, otherwise please give estimates

_____ kilograms (kgs) OR _____ stones (st) and _____ pounds (lbs)

B5. Given your age and height, would you say that you are:

Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight
☐	☐	☐	☐	☐

B6. Do you have any educational qualifications? (please tick all that apply or equivalents)

No qualifications	CSE, GCSE or 'O' Level	Vocational qualification (GNVQ, BTEC)	'A' or 'AS' level	Higher National Certificate (HNC) or Diploma (HND)	Undergraduate degree	Postgraduate qualification (Masters, PhD)
☐	☐	☐	☐	☐	☐	☐

Other, please describe: ________________________________

B7. Do you currently have a job?

On maternity leave	Yes, full-time	Yes, part-time	No	Stay at home to look after the children
☐	☐	☐	☐	☐

If NO, or stay at home to look after children please go straight to B9 on page 7

B8. What is your FULL job title? (please describe) ________________________________

Do you need any special qualifications for your job?

Yes ☐ No ☐ Unsure ☐

If YES, please describe:

____

B9. What is your ethnic group? Tick the appropriate box to indicate your cultural background

White	Black	Asian	Mixed	Chinese or any other
White British ☐	Caribbean ☐	Indian ☐	White and Black Caribbean ☐	Chinese ☐
White Irish ☐	African ☐	Pakistani ☐	White and Black African ☐	
		Bangladeshi ☐	White and Asian ☐	
Other White background ☐ (please specify) ______	Other Black background ☐ (please specify)	Other Asian background ☐ (please specify) ______	Other Mixed background ☐ (please specify)	Any other ☐ (please specify) ______

B10. Do you smoke cigarettes at all nowadays? Yes ☐ No ☐

If Yes, how many cigarettes a day do you usually smoke? ____ cigarettes per day

B11. Do you usually participate in the following activities? If so, how many times per week and for how long? (Write 0 if you do not participate in any activity)

Strenuous exercise (heart beats rapidly)
i.e. running, jogging, hockey, football, squash, vigorous swimming, vigorous cycling — ____ times per week ____ minutes per session

Moderate exercise (not exhausting)
i.e. fast walking, tennis, easy cycling, badminton, easy swimming, dancing — ____ times per week ____ minutes per session

Mild exercise (minimal effort)
i.e. yoga, fishing from river bank, bowling, golf, easy walking — ____ times per week ____ minutes per session

B12. In the last week about how many servings of .... did you eat?

	Less than 1 per week	1 per week	2-4 per week	5-6 per week	1 per day	2 per day	3 per day	4 or more per day
VEGETABLES (excluding potatoes)	☐	☐	☐	☐	☐	☐	☐	☐
FRUIT (fresh, frozen or canned)	☐	☐	☐	☐	☐	☐	☐	☐

B13. What is your marital status?

Married or cohabiting	Divorced	Widowed	Separated	Single
☐	☐	☐	☐	☐

If you are not married or cohabiting, please go to straight to D1 on page 10

ABOUT THE PERSON YOU LIVE WITH

(i.e. your husband or partner)

C1. What is your partner's relationship to the twins?

Natural father of the twins ☐ Legal guardian of the twins ☐ Other ☐

If other, please describe: ____________________

C2. What is your partner's date of birth? ____/____/______ (DD MM YYYY)

C3. About how tall is your partner?

_____ centimetres (cms) OR _____ feet (ft) and _____ inches

C4. About how much does your partner weigh? If possible, use weighing scales for current weights, otherwise please give estimates

_____ kilograms (kgs) OR _____ stones (st) and _____ pounds (lbs)

C5. Does your partner have any educational qualifications? (please tick all that apply or equivalents)

No qualifications	CSE, GCSE or 'O' Level	Vocational qualification (GNVQ, BTEC)	'A' or 'AS' level	Higher National Certificate (HNC) or Diploma (HND)	Undergraduate degree	Postgraduate qualification (Masters, PhD)
☐	☐	☐	☐	☐	☐	☐

Other, please describe: ____________________

C6. Does your partner currently have a job?

Yes, full-time ☐ Yes, part-time ☐ No ☐ Stay at home to look after the children ☐

If NO, or stay at home to look after children, please go straight to C8 on page 9

C7. What is your partner's FULL job title? (please describe) ____________________

Are there any special qualifications needed for their job?

Yes ☐ No ☐ Unsure ☐

If YES, please describe: ____________________

8

C8.	What is your partner's ethnic group? Tick the appropriate box to indicate your partner's cultural background			
White	**Black**	**Asian**	**Mixed**	**Chinese or any other**
White British ☐	Caribbean ☐	Indian ☐	White and Black Caribbean ☐	Chinese ☐
		Pakistani ☐	White and Black African ☐	
White Irish ☐	African ☐			
		Bangladeshi ☐	White and Asian ☐	
Other White background (please specify) ☐ ________	Other Black background (please specify) ☐ ________	Other Asian background (please specify) ☐ ________	Other Mixed background (please specify) ☐	Any other (please specify) ☐ ________

C9. **Does your partner smoke cigarettes at all nowadays?** Yes ☐ No ☐

If Yes, how many cigarettes a day does your partner usually smoke? ____ cigarettes per day

C10. **Does your partner usually participate in the following activities? If so, how many times per week and for how long?** (Write 0 if your partner does not participate in any activity)

Strenuous exercise (heart beats rapidly) i.e. running, jogging, hockey, football, squash, vigorous swimming, vigorous cycling	____ times per week	____ minutes per session
Moderate exercise (not exhausting) i.e. fast walking, tennis, easy cycling, badminton, easy swimming, dancing	____ times per week	____ minutes per session
Mild exercise (minimal effort) i.e. yoga, fishing from river band, bowling, golf, easy walking	____ times per week	____ minutes per session

C11. **In the last week about how many servings of .... did your partner eat?**

	Less than 1 per week	1 per week	2-4 per week	5-6 per week	1 per day	2 per day	3 per day	4 or more per day
VEGETABLES (excluding potatoes)	☐	☐	☐	☐	☐	☐	☐	☐
FRUIT (fresh, frozen or canned)	☐	☐	☐	☐	☐	☐	☐	☐

9

ABOUT OTHER CHILDREN IN THE HOME

D1. How many other children live in the home with your twins? (please write number)

__________ children

If there are no other children living in the home, please go straight to E1 on page 11

D2. Please tell us about all the children who live in the home with the twins:

Child's name	Date of birth	Sex		Does the child have the same mother as the twins?		Does the child have the same natural father as the twins?	
		Boy	Girl	Yes	No	Yes	No
__________	__/__/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	__/__/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	__/__/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	__/__/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	__/__/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	__/__/____ DD MM YYYY	☐	☐	☐	☐	☐	☐

If there are more than six other children or if there is anything else you would like to tell us about your family, please tell us in the open space below

YOUR PREGNANCY WITH THE TWINS

E1. **About how much weight did you gain during your pregnancy with the twins?**

_____ kilograms (kgs) OR ____ stones (st) and ____ pounds (lbs)

E2. **When you became pregnant with the twins, were you having any fertility treatment?** Yes ☐ No ☐

If YES, please describe: ____________________

E3. **Were you regularly taking any medicine whilst pregnant?** Yes ☐ No ☐

If YES, was this: (please tick all that apply) For first 3 months ☐ For middle 3 months ☐ For last 3 months ☐

Please describe the type of medication: ____________________

E4. **Did you smoke any cigarettes whilst pregnant?** Yes ☐ No ☐

If YES, was this: (please tick all that apply) For first 3 months ☐ For middle 3 months ☐ For last 3 months ☐

How many cigarettes a day did you smoke, on average? (write 0 if you smoked no cigarettes whilst pregnant) _____ cigarettes per day

E5. **Did you drink any alcohol whilst pregnant?** Yes ☐ No ☐

If YES, was this: (please tick all that apply) For first 3 months ☐ For middle 3 months ☐ For last 3 months ☐

How many units of alcohol did you drink per week, on average? (1 unit = 1 glass of wine, or 1 measure of spirits, or ½ a pint of beer) (write 0 if you drank no alcohol whilst pregnant) _____ units per week

E6. **Did you experience any severe stress during your pregnancy (e.g. bereavement, serious illness in the family or major money problems)?** Yes ☐ No ☐

If YES, please describe: ____________________

____

E7. During your pregnancy did you experience any of the following:

	Yes	No	Unsure
Morning sickness	☐	☐	☐
High blood pressure (pregnancy induced / gestational)	☐	☐	☐
Diabetes (pregnancy induced / gestational)	☐	☐	☐
Toxaemia / pre-eclampsia	☐	☐	☐
Vaginal bleeding	☐	☐	☐
Anaemia / iron deficiency	☐	☐	☐
Rubella / German Measles	☐	☐	☐
Slow growth of baby / babies	☐	☐	☐
Other serious pregnancy related problem (please describe)	☐	☐	☐

____

E8. Did you experience any physical or mental health problem in the first 6 months after birth; and were any of those problems diagnosed by a doctor?

Yes, diagnosed by a doctor ☐ Yes, but not diagnosed by a doctor ☐ No ☐

If YES, please describe: ________________________________

____

E9. Have you ever been diagnosed with heart disease or diabetes, before or after your pregnancy?

	Yes	No	Unsure
Heart disease	☐	☐	☐
Diabetes (unrelated to pregnancy)	☐	☐	☐

E10. In their lives, have any family members ever been diagnosed with heart disease or diabetes?

	Father of twins	Brother or sister of twins	Your mother	Your father	Mother of the twins' father	Father of the twins' father	None
Heart disease	☐	☐	☐	☐	☐	☐	☐
Diabetes	☐	☐	☐	☐	☐	☐	☐

E11. In general, how would you describe the weights of your family members throughout their lives?

	Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight	Unsure
Father of the twins	☐	☐	☐	☐	☐	☐
Your mother	☐	☐	☐	☐	☐	☐
Your father	☐	☐	☐	☐	☐	☐
Mother of the twins' father	☐	☐	☐	☐	☐	☐
Father of the twins' father	☐	☐	☐	☐	☐	☐

THE TWINS' BIRTH

F1. How many weeks pregnant were you at the time of delivery? _________ weeks

F2. Was the birth by Caesarean section?

Yes	No	Unsure
☐	☐	☐

If YES, why? ____

____

F3. Approximately how long was the gap between the births?

______ hours OR _______ minutes

F4. Did transfusion between twins occur (twin to twin transfusion syndrome)?

Yes	No	Unsure
☐	☐	☐

F5. Did your babies get a blood transfusion soon after birth?

Yes	No	Unsure
☐	☐	☐

F6. Were there any other complications or concerns about either twin <u>at birth</u>?

	Yes	No	Unsure
1st born	☐	☐	☐
2nd born	☐	☐	☐

If Yes in 1st born, please describe: ______________________________

____

____

____

If Yes in 2nd born, please describe: ______________________________

____

____

____

F7. Did either of the twins have any special care after birth (e.g. incubators)?

	Yes	No
1st born	☐	☐
2nd born	☐	☐

If Yes in 1st born, please describe: ______________________________

If Yes in 2nd born, please describe: ______________________________

F8. If yes, how long did they stay in special care?

1st born _____ days or _____ weeks

2nd born _____ days or _____ weeks

F9. How long did the twins stay in hospital after birth?

1st born _____ days or _____ weeks

2nd born _____ days or _____ weeks

F10. Do either of your twins have:

	Yes, 1st born	Yes, 2nd born	Neither
Physical problems (e.g. cleft lip, hole in the heart)	☐	☐	☐

If Yes in 1st born, please describe: ______________________________

If Yes in 2nd born, please describe: ______________________________

	Yes, 1st born	Yes, 2nd born	Neither
Genetic or chromosomal problems (e.g. Down's Syndrome, PKU)	☐	☐	☐

If Yes in 1st born, please describe: ______________________________

If Yes in 2nd born, please describe: ______________________________

	Yes, 1st born	Yes, 2nd born	Neither
Any other medical problem after birth	☐	☐	☐

If Yes in 1st born, please describe: ______________________________

If Yes in 2nd born, please describe: ______________________________

F11. **Sometimes it is difficult to start feeding due to birth-related complications or other medical problems. Straight after birth, did either of your twins experience any complications which made it difficult to start feeding?**

Yes, in 1st born ☐ Yes, in 2nd born ☐ No ☐

If Yes in 1st born, please describe: ______________________________

____

If Yes in 2nd born, please describe: ______________________________

____

F12. **Were there any other times when feeding your twins was difficult, e.g. due to illness of the twins, health problems of parent, changes in jobs or moving house.**

Yes, in 1st born ☐ Yes, in 2nd born ☐ No ☐

If Yes, please describe for each twin: (Use the back of the questionnaire if you need extra space)

Problem 1 in 1st born ______________________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

Problem 2 in 1st born ______________________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

Problem 1 in 2nd born ______________________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

Problem 2 in 2nd born ______________________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

15

THE TWINS' ILLNESSES AND ACCIDENTS

F13. About how many times have your babies seen the doctor due to illness or accidents since birth?

	Number of visits
1st born	________
2nd born	________

F14. Since birth, have your babies been admitted to hospital?

	No	Yes, once	Yes, more than once (write number)
1st born	☐	☐	________
2nd born	☐	☐	________

F15. Please briefly describe each hospital admission (Use the back of the questionnaire if you need more space)

	Age of twin (months)	Number of hospital nights	Reason for admission:
1st born	______	______	______________________
	______	______	______________________
	______	______	______________________
	______	______	______________________
	______	______	______________________
	______	______	______________________
2nd born	______	______	______________________
	______	______	______________________
	______	______	______________________
	______	______	______________________
	______	______	______________________
	______	______	______________________

18

SOME FINAL QUESTIONS ABOUT YOU AND YOUR FAMILY

G1. What is the main language spoken in the home?

English ☐ Other (please specify) ____________________

G2. Altogether, how many adults live in the same house as the twins (including yourself)?

One ☐ Two ☐ Three ☐ Four or more: _____ (please give number)

G3. How many bedrooms does your household have, including bedsitting rooms and spare rooms?

One ☐ Two ☐ Three ☐ Four or more: _____ (please give number)

G4. How many cars or vans are normally available for use by you or any members of your household?

None ☐ One ☐ Two ☐ Three or more: _____ (please give number)

G5. Do you currently own or rent the accommodation you live in?

Own without mortgage	Own with mortgage	Rent privately	Rent from local authority
☐	☐	☐	☐

G6. Thinking of the income of the household as a whole, which category represents the <u>total</u> income of your <u>whole household</u> before deduction from income tax, National Insurance etc.

Up to £15,000 per year	☐	Between £52,500 and £60,000 per year	☐
Between £15,000 and £22,500 per year	☐	Between £60,000 and £67,500 per year	☐
Between £22,500 and £30,000 per year	☐	Between £67,500 and £75,000 per year	☐
Between £30,000 and £37,500 per year	☐	Between £75,000 and £82,500 per year	☐
Between £37,500 and £45,000 per year	☐	Between £82,500 and £90,000 per year	☐
Between £45, 000 and £52,500 per year	☐	More than £90,000 per year	☐

G7. Do you feel your family income is enough?

More than enough ☐ Enough ☐ Not enough ☐

G8. Please give the date on which you completed this booklet? ___/___/___ day/month/year

Please continue with BOOKLET 2 to tell us more about your twins

17

Thank you

for filling out this booklet.

PLEASE continue with BOOKLET 2 to tell us more about your twins

Space for any additional comments you would like to make :

Family ID Number ☐☐☐☐☐☐

WELCOME TO

gemini

health and development in twins

Booklet 2 - Your Twins

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HOW TO FILL IN THIS BOOKLET

Thank you for agreeing to fill out this booklet. Before you start, here is a bit of guidance:

- We realise that parents of twins are very busy! We are especially grateful.
- We know the questionnaire is quite long, but please try to answer *all* the questions you are asked. This will help us to get a full picture of you and your twins' circumstances.
- Please be as honest as you can when answering our questions. We want to know what you really think. Everything you tell us will be kept strictly confidential.
- This may sound obvious, but please write as clearly as possible. This will help us use all the valuable information you have provided.

Here is an example of how a question *could* be answered.

Most of the questions in this booklet will ask you to tick a box next to the answer that is most suitable. Some will also ask you to describe this answer in more detail, for example:

A1.	**Do you think your twins are identical or non-identical?**	Identical	[√]	Non-identical	[ ]
	Why do you think this?	...The twins shared the same sac and placenta...			
A2.	**As your twins grow older, do you have more time for yourself?**	Yes	[√]	No	[ ]

THIS QUESTIONNAIRE IS TO BE COMPLETED BY THE MOTHER OF THE TWINS.
IF YOU ARE NOT THE MOTHER, PLEASE CONTACT US AND WE WILL SEND YOU THE APPROPRIATE QUESTIONNAIRE

THANK YOU FOR YOUR TIME AND ASSISTANCE IN FILLING OUT THIS BOOKLET

2

YOUR TWINS' GROWTH

First we would like to learn a bit more detail about your twins' growth. This information may be in your child's health record (little red book) or you may have kept your own records.

A1. What were the lengths of the twins at birth and around 6 weeks?

	1st born	2nd born
At birth	_____ cm or _____ inches	_____ cm or _____ inches
Around 6 weeks	_____ cm or _____ inches	_____ cm or _____ inches

A2. What were the head circumferences of the twins?

	1st born	2nd born
At birth	_____ cm or _____ inches	_____ cm or _____ inches
Around 6 weeks	_____ cm or _____ inches	_____ cm or _____ inches

A3. What were the weights of the twins?

	1st born	2nd born
At birth	_____ kg or ___ lbs ___ oz	_____ kg or ___ lbs ___ oz
Around 6 weeks	_____ kg or ___ lbs ___ oz	_____ kg or ___ lbs ___ oz

A4. Please add other weight measurements below together with the date they were taken. Use the back of the questionnaire if you need extra space. Alternatively you can send us a photocopy of the relevant pages from your twins' health records (little red book)

Date measured	1st born				2nd born				These measurements came from...		
	kg		lbs.	oz	Kg		lbs.	oz	Health professional / health record		Own measurements
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	___	or	___	___	___	or	___	___	☐	or	☐

3

Some parents worry about their babies being underweight or overweight for their age and sex. The following questions explore this in a bit more detail

A5. How would you describe your baby's weight at the moment?

	Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

A6. Have you ever been concerned that your baby wasn't gaining enough weight? (tick all that apply)

	Yes	No
1st born	☐	☐
2nd born	☐	☐

If No, please go straight to A8 on page 5

If yes, how old was your baby when you were concerned?

	0 - 3 months	4-6 months	7-9 months	10-12 months	Older than 1 year
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

A7. How concerned are you that your baby is underweight at the moment?

	Not concerned	Somewhat concerned	Very concerned
1st born	☐	☐	☐
2nd born	☐	☐	☐

If you are concerned about either baby being underweight, why is this? (please tick the most important reasons)

	1st born	2nd born
The health visitor/doctor advised me my baby is not gaining enough weight	☐	☐
Low centile on growth chart	☐	☐
My baby doesn't look as big as other babies of the same age and sex	☐	☐
My baby lost weight recently	☐	☐
My baby has always had a low weight	☐	☐
My baby is not feeding well	☐	☐
Family member(s) think my baby is not heavy enough. If so, who?__________	☐	☐
Other reason. If so, what? __________	☐	☐

4

A8. Have you ever been concerned that your baby <u>was gaining too much weight</u>?

	Yes	No
1st born	☐	☐
2nd born	☐	☐

If No, please go straight to B1 on page 6

If yes, how old was your baby when you were concerned?

	0 - 3 months	4-6 months	7-9 months	10-12 months	Older than 1 year
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

A9. How concerned are you that your baby is <u>overweight at the moment</u>?

	Not concerned	Somewhat concerned	Very concerned
1st born	☐	☐	☐
2nd born	☐	☐	☐

If you are concerned about either baby being <u>overweight</u>, why is this? (please tick the most important reasons)

	1st born	2nd born
The health visitor/doctor advised me my baby is gaining too much weight	☐	☐
High centile on growth chart	☐	☐
My baby looks bigger than other babies of the same age and sex	☐	☐
My baby gained weight recently	☐	☐
My baby has always had a high weight	☐	☐
My baby is feeding very vigorously	☐	☐
Family member(s) think my baby is too heavy. If so, who?_______________	☐	☐
Other reason. If so, what?_______________________________	☐	☐

____

5

YOUR FEEDING ROUTINE

Parents feed their babies in different ways, and we are interested in learning more about how you feed your twins. In the following questions, please think back to your twins' first three months of life

B1. Which of the following best describes each of your twins' eating routine during their first three months?

	I fed my baby whenever he/she cried, got fussy or seemed hungry	My baby was on a flexible feeding schedule (e.g. about every 3-4 hours)	My baby was on a rigid feeding schedule (e.g. I woke him/her up to eat on time)
1st born	☐	☐	☐
2nd born	☐	☐	☐

B2. Did you or the babies decide how often they should feed?

	Me only	Mostly me	Me and my baby equally	Mostly my baby	My baby only
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

B3. Did you or the babies decide how much milk they should take in a feed?

	Me only	Mostly me	Me and my baby equally	Mostly my baby	My baby only
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

B4. How would you classify your 'feeding philosophy' for each twin during their first three months?

	Feeding on demand (e.g. fed baby when he/she cried)	Feeding on a schedule (e.g. fed baby at set times)
1st born	☐	☐
2nd born	☐	☐

Now we would like to know more about how your feeding patterns have changed over time

By '**breastfeeding**', we mean any method of feeding breast milk, i.e. feeding directly from breast or giving expressed breast milk in a bottle

By '**bottle-feeding**', we mean feeding formula milk using a bottle

B5. Which feeding methods did you use in the first three months?

	1st born	2nd born
Entirely breastfeeding	☐	☐
Mostly breastfeeding with some bottle-feeding	☐	☐
Equally breastfeeding and bottle-feeding	☐	☐
Mostly bottle-feeding and some breastfeeding	☐	☐
Almost entirely bottle-feeding (only tried breastfeeding a few times)	☐	☐
Entirely bottle-feeding (never tried breastfeeding)	☐	☐
Other	☐	☐

If other, please describe: ______________________________

____

If you entirely bottle-fed your twins, please go straight to B10 on page 8

B6. How soon after birth did you start breastfeeding?

1st born Within..... _____ minutes or _____ hours or _____ days

2nd born Within..... _____ minutes or _____ hours or _____ days

B7. How easy was it to establish breastfeeding your twins?

	Very easy	Easy	All right	Difficult	Very difficult
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

B8. What was your main method of breastfeeding?

	Mostly fed directly from the breast	Equally fed directly from the breast and gave expressed milk	Mostly gave expressed breast milk
1st born	☐	☐	☐
2nd born	☐	☐	☐

B9. Are you currently breastfeeding your twins? Yes, 1st born ☐ Yes, 2nd born ☐ Neither ☐

If you are no longer breastfeeding, when did you stop?

1st born _______ weeks after birth

2nd born _______ weeks after birth

If you entirely breastfed your twins, please go straight to B17 on page 9

B10. How soon after birth did you start bottle-feeding your twins?

1st born Within.... _____ minutes or _____ hours or _____ days

2nd born Within.... _____ minutes or _____ hours or _____ days

B11. Why did you start bottle-feeding?

	1st born	2nd born
Following advice from health professional	☐	☐
Following advice from friends or family	☐	☐
Breastfeeding was too difficult	☐	☐
Baby did not gain enough weight on breast milk alone	☐	☐
Easier to fit into daily routine	☐	☐
Allows other people to feed my baby	☐	☐

If other, please describe ____

____

B12. Are you currently bottle-feeding your twins?

Yes, 1st born	Yes, 2nd born	Neither
☐	☐	☐

Now we are interested in learning more about <u>how much milk</u> your twins took. Because babies' milk requirements increase as they get older, it is easier to think about how much they took at one specific age. So to answer the questions, please think back to when they were <u>about three months old</u>

If you did not bottle-feed your twins at around 3 months, please go straight to B17 on page 9

B13. What size bottle did you normally use when the twins were <u>about three months old</u>?

	125ml / 4oz	250ml / 9oz	390ml / 12oz	Unsure
1st born	☐	☐	☐	☐
2nd born	☐	☐	☐	☐

8

B14. How full did you normally fill the bottle?

	Completely full	Mostly full	Half full or less	or	How much formula milk per bottle?
1st born	☐	☐	☐		____ ml or ____ oz
2nd born	☐	☐	☐		____ ml or ____ oz

B15. Most of the time, how much of the bottle did your babies drink?

	All of it	Most of it	Half or less	or	How much formula milk?
1st born	☐	☐	☐		____ ml or ____ oz
2nd born	☐	☐	☐		____ ml or ____ oz

B16. What size teat did you use when the twins were __about three months old__?

	Fast flow	Medium flow	Slow flow	Variable teat	Unsure
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

To answer the following questions, please think back to when your twins were __about three months old__

B17. On average, how many times did you feed your babies during each 24 hour period (one day and one night) when they were __about three months old__? Please write 0 if you did not breastfeed or bottle-feed your babies when they were about three months old

	Breastfeeding	and / or	Bottle-feeding
1st born	____ times per day		____ times per day
2nd born	____ times per day		____ times per day

B18. On average, how long did your babies feed for in a typical daytime feed when they were about three months old? Please write 0 if you did not breastfeed or bottle-feed your babies when they were about three months old

	Breastfeeding	and / or	Bottle-feeding
1st born	____ minutes per feed		____ minutes per feed
2nd born	____ minutes per feed		____ minutes per feed

HOW ACTIVE ARE YOUR TWINS

These questions ask about your twins' physical activity in their first three months of life.
For each behaviour, please indicate how often the baby did this

C1.	During feeding, how often did your babies ...		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	lie or sit quietly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	squirm or kick	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	wave their arms	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

C2.	During sleep, how often did your babies ...		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	toss about in the crib	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	move from the middle to the end of the crib	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	sleep in one position only	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

C3.	When being dressed or undressed, how often did your babies...		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	wave or kick	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	squirm or try to roll away	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

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C4. When put into the bath water, how often did your babies ...		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
splash or kick	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
squirm or turn around	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

C5. When placed on his/her back, how often did your babies ...		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
wave their arms or kick	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
squirm or turn around	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

C6. When placed in a seat (e.g. high chair, push chair, car seat), how often did your babies...		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
wave their arms or kick	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
squirm or turn their body	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
sit quietly	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

C7. How old were your babies when they first crawled on hands and knees?

1st born __________ months Not yet ☐

2nd born __________ months Not yet ☐

C8. How old were your babies when they could sit up without being supported?

1st born __________ months Not yet ☐

2nd born __________ months Not yet ☐

APPETITE

These questions are about your twins' appetite over their first three months of life.
We are specifically interested in the period when your twins were fed milk only,
i.e. no solid foods or pre-prepared baby food yet

D1. How would you rate your twins' appetites in their first three months?

	Poor	OK	Good	Very Good	Excellent
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

D2. Did either of your twins generally take more milk than the other in their first three months?

1st born took much more milk	1st born took a little more milk	Each took about the same amount	2nd born took a little more milk	2nd born took much more milk
☐	☐	☐	☐	☐

How would you describe your twins' feeding styles at a typical daytime feed in their first three months?

			Never	Rarely	Sometimes	Often	Always
D3.	My baby sucked vigorously	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D4.	My baby sucked steadily and rhythmically	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D5.	My baby seemed contented while feeding	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D6.	My baby frequently wanted more milk than I provided	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D7.	My baby loved milk	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

These are some more questions about how your twins feed. Again thinking back to the <u>first three months</u>, please choose which box is most appropriate for each of your babies

			Never	Rarely	Sometimes	Often	Always
D8.	My baby had a big appetite	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D9.	My baby finished feeding quickly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D10.	My baby became distressed while feeding	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D11.	My baby got full up easily	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D12.	If allowed to, my baby would take too much milk	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D13.	My baby took more than 30 minutes to finish feeding	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D14.	My baby got full before taking all the milk I thought he/she should have had	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D15.	My baby fed slowly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
D16.	Even when my baby had just eaten well he/she was happy to feed again if offered	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D17.	My baby found it difficult to manage a complete feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D18.	My baby was always demanding a feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D19.	My baby sucked more and more slowly during the course of a feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D20.	If given the chance, my baby would always be feeding	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D21.	My baby enjoyed feeding time	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D22.	My baby could easily take a feed within 30 minutes of the last one	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

HOW YOU FEED YOUR TWINS

The previous section asked some general questions about your feeding.

Now we are interested in learning more about how you fed your twins day-to-day over the first three months. We are particularly interested in whether you changed feeding in different situations

Again, thinking back to the first three months, please choose which box is most appropriate for each of your babies

			Never	Rarely	Sometimes	Often	Always
E1.	I knew when my baby was hungry	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E2.	I knew when my baby was full	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E3.	If my baby cried it was usually because he/she was hungry	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E4.	I worried if my baby did not feed much on one occasion	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E5.	If my baby wanted to be fed before the next scheduled feed, I fed him/her earlier than usual	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E6.	When my baby got fussy I tried feeding to settle him/her down	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E7.	I worried if my baby fed too much on one occasion	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

15

Still thinking back to the <u>first three months</u>, please choose for each of your babies which box is most appropriate

			Never	Rarely	Sometimes	Often	Always
E8.	I gave my baby a large feed to get him/her to sleep longer	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E9.	I fed my baby to keep him/her quiet when with others	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E10.	I was careful not to feed my baby too frequently	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E11.	I was careful not to feed my baby too large an amount	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
If my baby stopped feeding, I ...							
E12.	... tried other methods to encourage him/her e.g. moved baby into a different position or switched breasts	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E13.	... let him/her have a break then try again a bit later	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
If my baby didn't feed much on one occasion, I ...							
E14.	... made sure he/she took a larger amount at the next feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E15.	... offered him/her another feed a bit sooner than I normally would	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

Please only answer these questions if you ever bottle-fed either of your twins during the first three months

If you entirely breastfed your twins, please go straight to F1 on page 18

			Never	Rarely	Sometimes	Often	Always
E16.	I tried to make my baby finish everything in the bottle	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E17.	If my baby finished the bottle quickly, I made up another	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E18.	If I worried my baby wasn't eating enough, I added a bit more formula in his/her bottle	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E19.	If I worried my baby was not feeding enough I changed to a more filling formula	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

Please only answer these questions if you fed your twins with a mixture of bottle-feeding and breast-feeding during the first three months

If you entirely bottle-fed your twins, please go straight to F1 on page 18

			Never	Rarely	Sometimes	Often	Always
E20.	If my baby was still hungry after a breast-feed, I fed him/her a bottle	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E21.	I fed my baby by breast, but gave a bottle before bed to help encourage sleep through the night	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

SOLID FOODS

The following section is about <u>solid foods</u>
(i.e. anything other than milk, including mashed up foods and ready prepared baby food)

If neither of your twins has started solid foods, please go straight to F12 on page 21

F1. How old were the twins the very first time solid foods of any kind were eaten (i.e. anything other than milk)?

1st born ____ weeks or ____ months Not yet ☐

2nd born ____ weeks or ____ months Not yet ☐

F2. How easy was it to wean your twins onto solid food?

	Very easy	Easy	OK	Difficult	Very difficult
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

F3. How did you decide to start the twins on solid foods?

	1st born	2nd born
Following advice from health professional	☐	☐
Following advice from friends or family	☐	☐
Milk alone was not enough	☐	☐
Easier to fit into family routine	☐	☐
Baby showed interest in solid foods	☐	☐
Allergy to milk	☐	☐
Other, please describe:	☐	☐

1st born ____

____

2nd born ____

____

18

F4. In general how much did your baby enjoy starting solid foods?

	Did not enjoy it at all	Enjoyed it a little	Enjoyed it a lot
1st born	☐	☐	☐
2nd born	☐	☐	☐

F5. Have your twins started taking solid foods <u>every day</u>?

	Yes	No
1st born	☐	☐
2nd born	☐	☐

If No, please go straight to F8 on this page

F6. At what age did your twins start taking solid foods <u>every day</u>?

1st born ________ months old

2nd born ________ months old

F7. At present, how many times per day does your baby have solid foods?

1st born ______ times per day

2nd born ______ times per day

F8. When eating solid food, which of the following statements describes your twins' feeding most accurately?

	Generally needs to be fully fed by an adult	Generally needs to be fed by an adult but also eats with fingers	Generally eats with spoon but needs help	Generally eats with spoon without help
1st born	☐	☐	☐	☐
2nd born	☐	☐	☐	☐

F9. When were your twins first given finger foods (i.e. foods babies can pick up and feed to themselves)?

1st born Age ________ months Not yet ☐

2nd born Age ________ months Not yet ☐

F10. Has either of your twins tried these foods yet? If so, how old were they when they first tried it?			
		Age when first tried	Not yet tried
Baby rice, cereal, rusks or bread	1st born	______ months	☐
	2nd born	______ months	☐
Vegetables (uncooked, cooked or pureed, fresh, frozen or tinned)	1st born	______ months	☐
	2nd born	______ months	☐
Chips (e.g. oven fries, smiley faces, potato waffles or wedges)	1st born	______ months	☐
	2nd born	______ months	☐
Potatoes or sweet potatoes	1st born	______ months	☐
	2nd born	______ months	☐
Processed meat (e.g. sausages, burger)	1st born	______ months	☐
	2nd born	______ months	☐
Other meat (e.g. chicken, lamb, pork, beef)	1st born	______ months	☐
	2nd born	______ months	☐
Fish (fresh, frozen, tinned or fish fingers)	1st born	______ months	☐
	2nd born	______ months	☐
Eggs	1st born	______ months	☐
	2nd born	______ months	☐
Dairy products (e.g. milk, cheese, yoghurt)	1st born	______ months	☐
	2nd born	______ months	☐
Fizzy drinks with sugar (e.g. 7up, coke)	1st born	______ months	☐
	2nd born	______ months	☐
Low calorie fizzy drinks (e.g. 7up zero, diet coke)	1st born	______ months	☐
	2nd born	______ months	☐

F11. **Has either of your twins tried these foods yet? If so, how old were they when they first tried it?**

		Age when first tried	Not yet tried
Squash and/or fruit drinks with sugar (e.g. ribena, robinsons fruit shoot)	1st born	_______ months	☐
	2nd born	_______ months	☐
Low calorie squash and/or fruit drinks (e.g. ribena light, robinsons fruit shoot no added sugar)	1st born	_______ months	☐
	2nd born	_______ months	☐
Pure fruit juice (100% juice)	1st born	_______ months	☐
	2nd born	_______ months	☐
Savoury snacks (e.g. crisps, cheese biscuits)	1st born	_______ months	☐
	2nd born	_______ months	☐
Fruit (uncooked, cooked, pureed, fresh, frozen or tinned)	1st born	_______ months	☐
	2nd born	_______ months	☐
Sweet snacks (e.g. cakes, biscuits, ice cream)	1st born	_______ months	☐
	2nd born	_______ months	☐
Sweets (e.g. chocolate, fruit sweets)	1st born	_______ months	☐
	2nd born	_______ months	☐

F12. **Please give the date on which you completed this booklet?** ___/___/_____ DD MM YYYY

Thank you

very much for filling in this booklet

PLEASE CHECK that you have given details on <u>YOUR TWINS' GROWTH on page 3</u> or send us copies of the relevant pages from your twins health records (little red book)

Space for any additional comments you would like to make

Appendix 3.4 Gemini information leaflet

Do I have to take part?

It is up to you to decide whether to take part. If you choose not to participate it will involve no penalty or loss of benefits to which you are otherwise entitled. If you decide to take part you have this information sheet to keep and you will be asked to sign a consent form. If you decide to take part now, you are still free to withdraw at any time without giving a reason.

How can I take part in Gemini?

If you are interested in taking part in Gemini, please fill out the reply slip and return it in the enclosed envelope to ONS.

The more families that agree to take part, the more valuable the study will be. The team looks forward to your response.

Who has approved this study?

This study has been reviewed and approved by Cancer Research UK and UCL/UCLH Research Ethics Committee.

Who is running the study?

Gemini is being conducted by the Health Behaviour Research Centre, which is part of University College London. The study has been financed by Cancer Research UK, because of their interest in healthy food choices.

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE
UCL

For further information, please contact us:

T 020 7679 6643
E Gemini@public-health.ucl.ac.uk

Professor Jane Wardle - Principal Investigator
Dr Ellen van Jaarsveld - Study Coordinator
Ms Clare Llewellyn - Researcher
Dr Laura Johnson - Researcher
Ms Rebecca Marlow - Administrative Assistant

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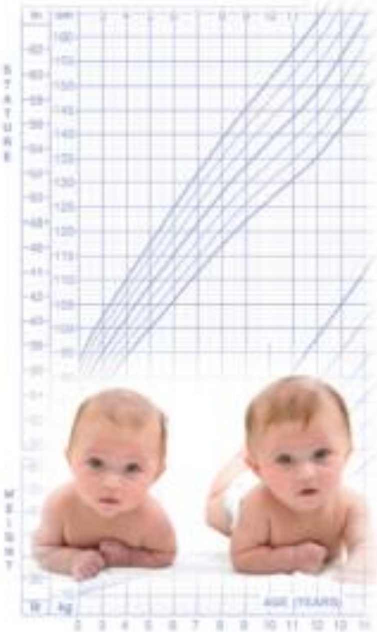

Information leaflet

gemini

health and development in twins

We are inviting you to join our new research project - Gemini. We are asking you because you have had twins – congratulations! Twins are very special to their parents. They are also very interesting to researchers because studying them can tell us about how genes and environments work together.

You should only take part if you want to; choosing not to participate will not disadvantage you in any way. Before you decide, you should read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or you want more information.

What is Gemini?

Gemini is a new national study following 2,400 parents and their twins through their first five years. We shall be interested in the twins' health, eating habits and activity with a main focus on appetite and weight gain. We are also interested in parents' attitudes and aspects of the home situation.

What does taking part involve?

Each year, we would like to send you questionnaires about your twins' development. A freepost envelope will be enclosed for easy return of the questionnaires. We can also offer a web-based version if that is easy for you. The information you provide will remain completely confidential. The questionnaire should take no longer than 90 minutes to complete.

Selecting families

The General Register Office (part of the Office for National Statistics or ONS) have identified your name as the mother of twins from their Birth Registration database. They are helping the Gemini study by contacting families with newborn twins. Names and addresses will only be made available to Gemini by ONS when parents have agreed to participate. Only families in England and Wales with registered twin births in 2007-2008 will be contacted.

Anticipated benefits to you and your family

Being part of Gemini should be interesting and fun! Families involved in an earlier study in which twins were followed from age 4 to 11 years have told us they enjoyed the experience.

One parent said, "I thought I would be too busy to do the study but I found it was an opportunity to stop and reflect about my twins and our life together as a family. It was time well spent!"

"I think it's great that my twins are part of the study and they think they're pretty special for being selected" said another parent.

"I've enjoyed reading the newsletter and read about some twins being very similar and others being totally different" said another parent.

Will the information I give remain confidential?

Yes. The privacy of the families and twins taking part in the study is strictly protected. All information collected about you and your child during the course of the research will be kept strictly confidential. The research team will not pass on your personal details to anyone else. Professional standards of confidentiality will be adhered to and all data will be collected and stored in accordance with the Data Protection Act 1998.

How will the information be used?

The information collected in the study will help us learn more about children's growth and health. It could also help the government to plan policies and services that benefit families and children. We will report our findings in academic and health-related journals and present them to relevant health professionals at meetings and conferences. You will not be identified in any reports or publications arising from the study.

Appendix 3.5 Gemini consent form

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DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

CONSENT FORM

Title of Project: Gemini – health and development in twins

Study Reference: 07/H0714/116 Family ID number:

Name of Researchers: *Professor Jane Wardle, Dr. Ellen van Jaarsveld*

Please initial box

1. I confirm that I have read and understood the information leaflet for the above study which I received with the invitation letter. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I confirm that I have had sufficient time to consider whether or not I want to be included in the study. ☐
3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐
4. I consent to the processing of my personal information for the purposes of this study, and that it will not be used for any other purpose. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998. ☐
5. I agree to be contacted in the future by the Gemini team who would like to invite me to participate in follow-up studies. ☐
6. I understand that the information I have submitted will be published as a report. Confidentiality and anonymity will be maintained and it will not be possible to identify me from any publications. ☐
7. I understand that some study documents may be looked at by responsible representatives from the Research & Development Unit, UCL to ensure that the study is being conducted properly. My identity will be protected at all times. ☐
8. I agree to take part in the above study. ☐

Name of Participant	**Date**	**Signature**
Name of Researcher: Jane Wardle	**Date**: 23 / 07 / 2008	**Signature**: Jane Wardle

When completed: Please keep 1 copy for your own records; and send 1 copy back to:
Gemini, Health Behaviour Research Centre, UCL, 2-16 Torrington Place, London, WC1E 6BT

Appendix 3.6 Child Eating Behaviour Questionnaire (CEBQ) – seven year version

APPETITE

These questions are about the twins' appetites

How would you describe your twins' eating styles on a typical day?

			Never	Rarely	Sometimes	Often	Always
1.	**My child loves food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
2.	**My child has a big appetite**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
3.	**My child finishes his/her meal quickly**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
4.	**My child is interested in food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
5.	**My child refuses new foods at first**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
6.	**My child eats slowly**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
7.	**My child enjoys tasting new foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
8.	**My child is always asking for food**	1st born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
		2nd born	☐	☐	☐	☐	☐
9.	If allowed to, my child would eat too much	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
			Never	Rarely	Sometimes	Often	Always
10.	My child enjoys a wide variety of foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
11.	My child leaves food on his/her plate at the end of a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
12.	My child takes more than 30 minutes to finish a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
13.	Given the choice, my child would eat most of the time	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
14.	My child looks forward to mealtimes	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
15.	My child gets full before his/her meal is finished	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
16.	My child enjoys eating	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
17.	My child is difficult to please with meals	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
18.	My child gets full up easily	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
19.	Even if my child is full up he/she finds room	1st born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
20.	**My child cannot eat a meal if he/she has had a snack just before**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
21.	**My child is interested in tasting food he/she hasn't tasted before**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
22.	**My child decides that he/she doesn't like a food without even tasting it**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
23.	**If given the chance my child would always have food in his/her mouth**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
24.	**My child eats more and more slowly during the course of a meal**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

Appendix 3.7 Instructions for measuring height

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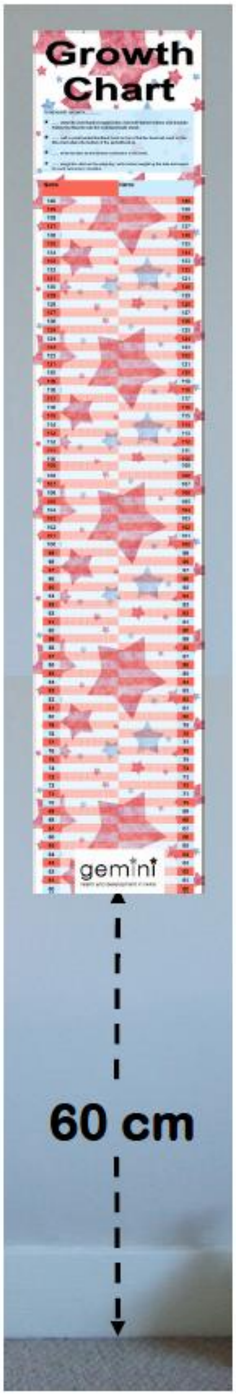
HOW TO USE THE GEMINI GROWTH CHART

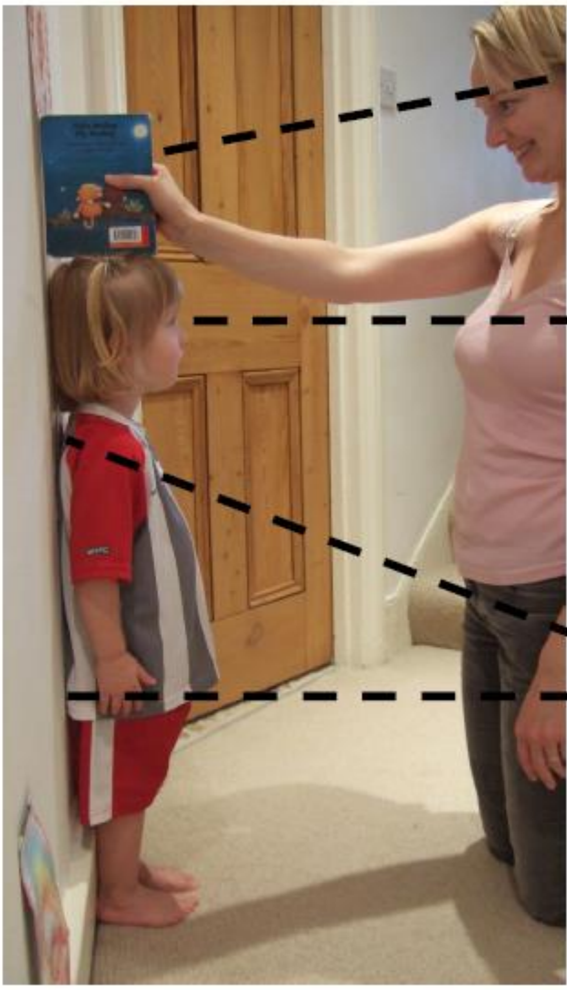
STEP 1:
Fix the chart to a wall 60cm above the floor.

- You can also fix the growth chart to a door or a large cupboard.
- You can use the growth chart to measure 60 cm from the floor. Just place the bottom of the chart on the floor, flat against the wall and mark on the wall where it shows 120 cm on the chart.
- The mark you have made will show you where the bottom of the chart should be when it is on the wall.
- Once the chart is fixed to the wall check that the bottom of the chart is in line with the mark you made to confirm that the chart is 60 cm from the floor.



STEP 2:

Ask your child to stand up straight against the wall in front of the growth chart.



Place the spine of a book upright and flat against the wall above your child's head.

Eyes looking straight ahead.

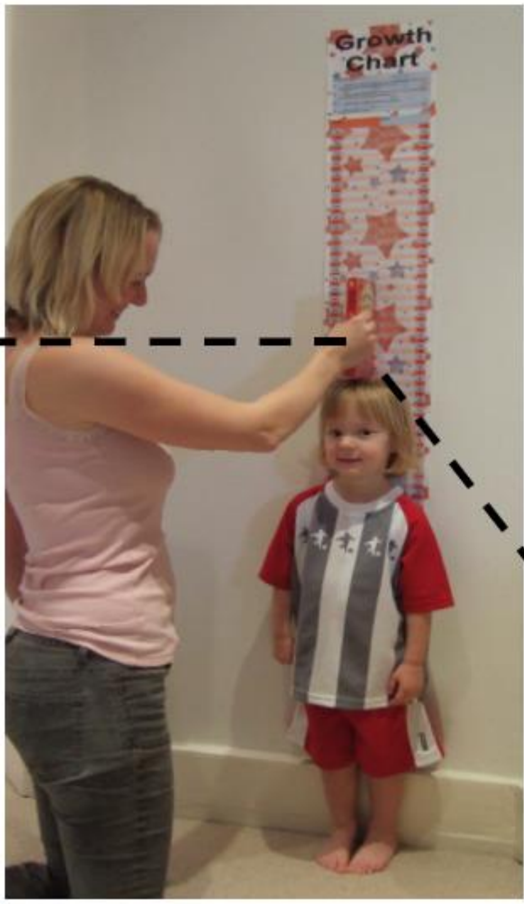
Make sure your child's shoulder blades and bottom are touching the wall.

STEP 3:

Place the long edge of a book* upright and flat against the wall so that it lightly touches the top of your child's head.

*Instead of a book you could use the side of a cereal packet placed upright and flat against the wall.

Lower the book down the wall slowly until it lightly touches your child's head.

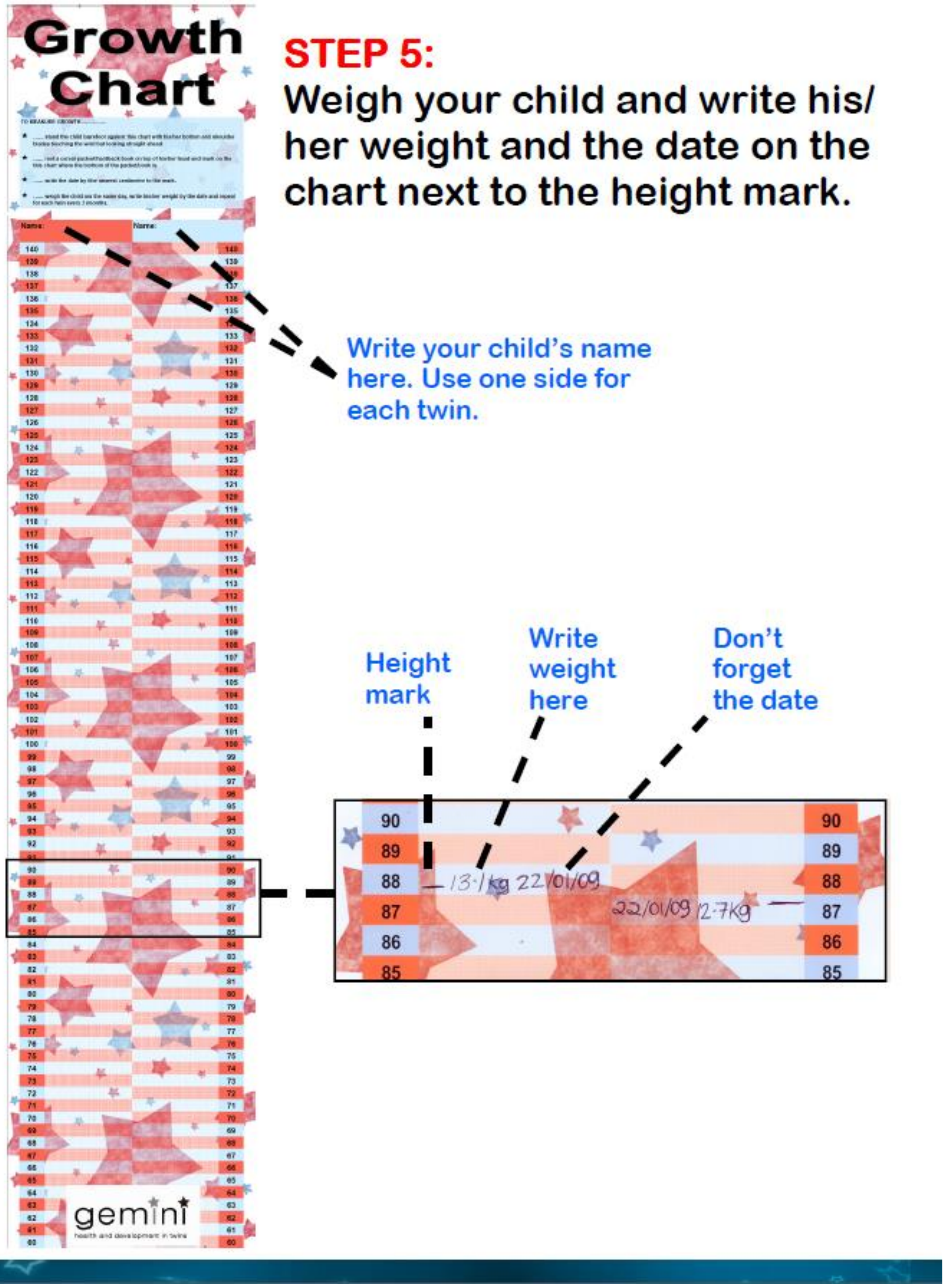


Draw a line here on the chart where the bottom of the book touches your child's head.

STEP 4:

Mark on the chart at the bottom of the book while it is touching your child's head.

STEP 5:
Weigh your child and write his/ her weight and the date on the chart next to the height mark.



Appendix 3.8 21 month diet diary

Family ID Number

WELCOME TO

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Food and Drink Diary

Health Behaviour Research Centre, Department of Epidemiology & Public Health, UCL
2-16 Torrington Place, London, WC1E 6BT
gemini@public-health.ucl.ac.uk
020 7679 6629

TOP TIP
If any details are exactly the same for twin 2 as for twin 1 feel free to write "as above" in the appropriate sections rather than writing it out twice.

MORNING and EARLY AFTERNOON
Twin 2 Name …*Gemma*………………

Day 1		**Date** ***04/09/2008***			
Time	**Where? With whom? TV on? At table?**	**Food/Drink description & preparation**	**Brand Name**	**Portion size or quantity eaten**	**Meal or Snack?**
8.30	*Bedroom,*	*Biscuit for Babies + Toddlers*	*Cow and Gate*	*1 biscuit*	*Snack*
am	*no TV, Mother*				
10am	*As above*	*Rice Krispies*	*Kellogg's*	*Photo 8B*	*Meal*
		Whole milk	*Sainsbury's*	*110 ml*	
11.30	*Garden, no TV*	*Pure apple and blackcurrant juice*	*Heinz*	*60ml juice*	*Snack*
am	*Granddad*	*diluted with water*	*Tap*	*240ml (¼ left)*	
1pm	*As above*	*Vegetables with Noodles and Chicken*	*HIPP*	*250g*	*Meal*
		(12months)			
		Peeled apple, sliced		*½ of apple size*	
				photo 16C	
		Frutapura, Plum and Apple	*Cow and Gate*	*1x 100g pot*	

Don't forget to estimate portion sizes for ALL foods and drinks recorded.

Appendix 3.9 21 month diet diary invitation letter

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DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE
UCL

<Mothers firstname> <Mothers Lastname>
<Address line1>
<Address line 2>
<Address line 3>
<Postcode>

<Date>

Family ID Number: GEM XXXX

Dear <Mothers firstname>,

Thank you for staying with the Gemini study. We hope that you and your family are well.

You may recall when your twins were approximately 20 months old we asked you to complete a **food diary** to help us find out what and when they eat and drink. **THANK YOU** so much if you completed this for us! You have helped to provide us with the richest dietary dataset for toddlers in the UK. Because of the success of the last diary, we are interested in doing this again now that the Gemini twins are older.

Food and drink diary
We enclose a diary in which we would like you to tell us about your twins' eating and drinking for **three days**, ideally two weekdays and one weekend day, when you are with them and can record exactly what they consumed.

We hope you will be able to fill in the diary for three days. If you cannot manage the whole of the three days, one or two complete days are still extremely helpful to us.

We have provided **detailed instructions in the diary** and an example of how we would like you to record your twins' diets. The main instructions are summarised below and should help you get started.

- **Please record everything your twins eat and drink for three day (inside and outside of the home).** Each day of recording should start at midnight.
- **Please choose three days** that are convenient for you. The three days need not be one after the other. If any day is likely to be very difficult or unusual choose another day.
- **Use the food and portion guide** enclosed to help with the kind of details we need about the foods your twins eat and how to estimate how much they eat or drink.
- **Please read the instructions in the diary carefully before you start**. If in doubt **please write down as much information as possible** as this will help us get the clearest picture of your twins diets.

Questionnaire
As I'm sure you will have gathered over the past 7 years, the Gemini team would hate to miss an opportunity to gather as much information from you as possible! So as well as asking you to complete the diary we would be very grateful if you could also complete the short questionnaire enclosed. It asks about **appetite**, **sleep patterns** and **allergies**, and should take no more than 10 minutes.

Please send the **completed diary and questionnaire back to us** (we do not need the portion guides returned) in the **freepost** envelope enclosed (no stamp required). Any data you can provide us with is very valuable to our study.

If you have any problems or queries please contact the Gemini team (Hayley, Clare, Laura, Abi) by telephone on **020 7679 1263** or by email at **gemini@.ucl.ac.uk.**

Kind regards,

Professor Jane Wardle

Appendix 3.10 21 month portion guide

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Food and portion guide

8. Ice-cream

9. Mixed vegetables

10. Potatoes

11. Pasta

Food	***Description & Preparation***	***Portion size or quantity***
Ice cream	*Flavour; dairy or non-dairy; brand name; luxury/premium; added nuts, fruit*	• Number of spoons – choose spoon size in photo 20 • Estimate amount with photo 8
Jam, honey, marmalade	*What sort; type and brand; low-sugar/diabetic; thick-cut; shop bought/homemade*	• Number of spoons – choose spoon size in photo 20 • Spread thin/medium/thick
Meat (see also bacon, burgers & sausages)	*What sort; cut of meat e.g. chop, breast, minced; lean or fatty; fat removed or eaten; skin removed or eaten; how cooked; with or without gravy*	• Estimate amount with photo 18 (sausages); photo 13 (sliced meat) • Number of spoons e.g. mince – choose spoon size in photo 20
Milk	*Brand and type (whole, semi-skimmed, skimmed); fresh, sterilized, UHT, dried; soya milk (sweetened/unsweetened), goats' milk, rice milk; flavoured; fortified with added vitamins and/or minerals; formula milks for toddlers*	• Volume in fl oz / ml *For formula:* • Amount of powder in scoops/spoons - choose spoon size in photo 20 • Amount of water added in fl oz / ml
Nuts	*What sort and brand; dry roasted, ordinary salted, honey roasted; unsalted*	• Weight and/or portion of a single packet e.g ¼ of 100g packet • Number of whole nuts or packets (with weight of packet)
Pie (sweet or savoury)	*What sort and brand; individual or helping; one pastry crust or two; type of pastry*	• Weight of whole pie and/or slice e.g. ¼ of 200g pie
Pizza	*Thin base or deep pan or French bread; topping; brand name and type*	• Weight of whole pizza and/or slice e.g. $^1/_8$ of 190g pizza • Estimate size of pizza with photo 19
Porridge	*Brand name; made with oats or cornmeal or instant oat cereal; made with milk and/or water; with sugar or honey; with milk or cream*	• Number of spoons of dry oats – choose spoon size in photo 20 • Number of packets (including weight) • Volume of milk/water added fl oz/ml
Potatoes (see also chips)	*Old or new; baked, boiled, roast (type of oil/fat); skin eaten; mashed (with butter/spread and with or without milk); fried/chips (type of oil/fat); instant; any additions e.g. butter*	• Estimate amount with photo 5 (chips), 10 (boiled/roast) • Number of spoons e.g. mash – choose spoon size in photo 20
Pudding (see also ice-cream / yoghurt)	*What sort; e.g. steamed sponge; with fruit; mousse; instant desserts; milk puddings*	• Number of spoons – choose spoon size in photo 20 • Weight on packet e.g. 60g • Estimate amount with photo 4 (cake), 9 (Ice-cream)

Appendix 3.11 Diet diary pilot invitation email

Hi,

I hope that this email finds both you and your family well.

My name is Laura Johnson and I am a researcher on the Gemini twin study at University College London. I am contacting you because you have previously expressed an interest in helping us pilot the measures we plan to use in the main Gemini Study.

We would like to find out more about what young children are eating and have developed a food diary in which mothers can record everything their twins eat for 3 days.

We know that this is quite a task for mothers with just one baby to do, but with twins it must be even harder. We have tried to make the diary as easy to use as possible by combining both twins into one book and also providing a portion size guide to help with estimating how much food the twins eat.

It would be great if you have some time to complete a 3 day diary for your twins and give us feedback. Please reply to this email if you think you can help us and we will send you a diary and portion guide to complete.

Thanks very much for your help

Best wishes

Laura

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gemini - health and development in twins
Cancer Research UK Health Behaviour Research Centre
Dept of Epidemiology and Public Health
University College London
2-16 Torrington Place
WC1E 6BT
gemini@public-health.ucl.ac.uk
Tel: 020 7679 6643
Fax: 020 7813 2848gov.uk, deefer@ntlworld.com, samboyle@hotmail.com

Appendix 3.12 Diet diary pilot letter

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DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

30th July 2008

Family ID Number:

Dear

Thank you for agreeing to help the Gemini study. Pilot work is essential for us to ensure that our questionnaires are understandable and easy to use. Your help with this part of our study is invaluable.

Please find enclosed a food diary and an accompanying food and portion guide. We hope you will be able to fill the diary for three days. If you cannot manage the whole of the three days, one or two complete days are extremely helpful to us. The instructions below will help you fill in the diaries.

Please record everything your twins eat and drink for 3 days that are convenient for you in the next week. Each day of recording should start at 6 am and end at 6am the following morning. **Please choose one weekend day and two week-days.** The three days need not be one after the other. If any day is likely to be very difficult or unusual choose another day.

We have provided **detailed instructions in the food diary** and an example of how we would like you to record your twins' diet. **Please read these instructions carefully before you start**. A food and portion guide has been supplied to help you know the kind of details we require on the foods eaten and to help you estimate how much was eaten or drunk.

If in doubt **please write down as much detail as possible** as this will help us get the clearest picture of your twins diets.

Once you have finished recording please send the completed diary along with the food and portion guide back to us in the freepost envelope enclosed (no stamp required). Once you have returned the diary we should like to contact you by telephone to discuss your thoughts on how you found completing the diary. If you are happy for us to call you then please complete and return the enclosed form to let us know your telephone number and availability for a phone call.

If you have any problems or queries please contact Laura Johnson by telephone on 020 7679 6629 or by email at l.johnson@public-health.ucl.ac.uk.

Many thanks again for helping us out.

Kind regards,

Laura Johnson
Research Associate

Appendix 3.13 Diet diary pilot feedback questions

Diet diary pilot feedback form

Good morning, is now a convenient time to talk about the diary you recently completed?

Thank you very much for completing a diary for us. I have sent a copy of the diary you completed back to you in the post, have you received it?

Hopefully this will help you remember how you found completing the diary……..so to start I have a few general questions…………….

General

How did you find completing the diary in general?

How awkward?

How time consuming?

Would you do it again? Yes No

Text:

Was the text easy to read? Yes No

Do you think the text needs to be bigger? Yes No

Wider spaced? Yes No

If yes, where?

Layout:

What did you think of the layout (order of sections e.g. instructions, questions, diary)?

Easy to follow/understand? Yes No

Did you have enough space to write answers? Yes No

Instructions: were they clear / extensive enough

Did you read the instructions before beginning the diary? Yes No
If not, why not?

Having read the instructions did you have any queries or problems completing the diary at all?

When did you most often complete the diary?

a) when you put food on the plate?
b) Just after each eating occasion?
c) At the end of each day?
d) In the following days?

Was the example clear / helpful? Yes No

Questions:
A few mothers did not respond to the question we asked about the general size of the bowl used by their twins, how did you find responding this question?

Was it difficult? Why?

We were thinking of adding an instruction to help mums answer this question, "please estimate the size or your child's bowl by filling it with water and then measuring the amount of water in a measuring jug"
Would you find this helpful? Yes No

If we added a general question about how you generally make up formula for your children would you be able to answer it? i.e. the amount of powder and water

Yes No

Were any of the other questions unclear or difficult to respond to?

Were the response options appropriate?

The diary:

How did you find the process of providing the information in each of the columns?

Time	Fine	Difficult
Where	Fine	Difficult
With whom	Fine	Difficult
Food description and preparation	Fine	Difficult
Brand name	Fine	Difficult
Portion size	Fine	Difficult
Meal or snack	Fine	Difficult

In situations where both of your twins had the same food, how did find recording the same information twice?

How did you find the time sections? Were they relevant your child's eating patterns?

Portion size guide:

How did you find the process of estimating portions sizes for your children?

Were there any foods you found particularly difficult to estimate the portion size eaten?

Would you find it easier to record the amount of food served followed by the amount left over (if any) rather than estimating the amount of food eaten by your twins?

Yes No

ONLY IF PHOTOS WERE USED…………

Did you find the photographs helpful for estimating portion size?
Yes No

Did you find the amounts shown in the pictures relevant to what your twins ate?
Yes No

Did you find the foods relevant to what your twins ate?
Yes No

THANK YOU VERY MUCH for talking to me today. It's been really helpful getting your views.

Would you ike to help us with pilot work again in the future?

Yes No

OK we will update the database to show that.
Thanks again……………Good bye.

Appendix 3.14 Seven year diet diary invitation letter

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE

<Mothers firstname> <Mothers Lastname>
<Address line1>
<Address line 2>
<Address line 3>
<Postcode>

<Date>

Family ID Number: GEM<UCLID>

Dear <Mothers firstname><

Thank you for staying with the Gemini study. We hope that you and your family are well.

You may recall when your twins were approximately 20 months old we asked you to complete a **food diary** to help us find out what and when they eat and drink. **THANK YOU** so much if you completed this for us! You have helped to provide us with the richest dietary dataset for toddlers in the UK. Because of the success of the last diary, we are interested in doing this again now that the Gemini twins are older.

Food and drink diary
We enclose a diary in which we would like you to tell us about your twins' eating and drinking for **three days**, ideally two weekdays and one weekend day, when you are with them and can record exactly what they consumed.

We hope you will be able to fill in the diary for three days. If you cannot manage the whole of the three days, one or two complete days are still extremely helpful to us.

We have provided **detailed instructions in the diary** and an example of how we would like you to record your twins' diets. The main instructions are summarised below and should help you get started.

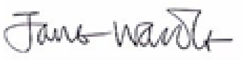
- **Please record everything your twins eat and drink for three day (inside and outside of the home).** Each day of recording should start at midnight.
- **Please choose three days** that are convenient for you. The three days need not be one after the other. If any day is likely to be very difficult or unusual choose another day.
- **Use the food and portion guide** enclosed to help with the kind of details we need about the foods your twins eat and how to estimate how much they eat or drink.
- **Please read the instructions in the diary carefully before you start**. If in doubt **please write down as much information as possible** as this will help us get the clearest picture of your twins diets.

Questionnaire
As I'm sure you will have gathered over the past 7 years, the Gemini team would hate to miss an opportunity to gather as much information from you as possible! So as well as asking you to complete the diary we would be very grateful if you could also complete the short questionnaire enclosed. It asks about **appetite**, **sleep patterns** and **allergies**, and should take no more than 10 minutes.

Please send the **completed diary and questionnaire back to us** (we do not need the portion guides returned) in the **freepost** envelope enclosed (no stamp required). Any data you can provide us with is very valuable to our study.

If you have any problems or queries please contact the Gemini team (Hayley, Clare, Laura, Abi) by telephone on **020 7679 1263** or by email at **gemini@.ucl.ac.uk**.

Kind regards,



Professor Jane Wardle

Appendix 3.15 Seven year diet diary

Family ID Number ☐☐☐☐☐☐☐

WELCOME TO

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health and development in twins

Food and Drink Diary

Health Behaviour Research Centre, Department of Epidemiology & Public Health, University College London
1-19 Torrington Place, London, WC1E 6BT
gemini@ucl.ac.uk
020 7679 1263

TOP TIP
If any details are exactly the same for twin 2 as for twin 1 feel free to write "as above" in the appropriate sections rather than writing it out twice.

MORNING and EARLY AFTERNOON

Twin 2 Name …*Gemma*……………….

Day 1		**Date** ***04/05/2014***			
Time	**Where? With whom? TV on? At table?**	**Food/Drink description & preparation**	**Brand Name**	**Portion size or quantity <u>eaten</u>**	**Meal or Snack?**
8.30	*Bedroom,*	*Strawberry and Raspberry Yoghurt*	*Petit Filous*	*60g*	*Snack*
am	*no TV, Mother*				
10am	*As above*	*Rice Krispies*	*Kellogg's*	*Photo 8B*	*Meal*
		Whole milk	*Sainsbury's*	*160 ml*	
		Wholemeal toast (medium cut)	*Hovis*	*1 slice*	
		Margarine	*Flora light spread*	*medium spread*	
11.30	*Garden, no TV*	*Apple and blackcurrant squash*	*Robinsons*	*40ml juice*	*Snack*
am	*Granddad*	*diluted with water*	*Tap*	*240ml (¼ left)*	
1pm	*As above*	*Shepherd's Pie*	*Waitrose*	*400g (3/4 eaten)*	*Meal*
		Broccoli		*Photo 3C*	
		Peeled apple, sliced		*Whole apple*	
				photo 16B	

Don't forget to estimate portion sizes for ALL foods and drinks recorded.

Food	*Description & Preparation*	*Portion size or quantity*
Ice cream	*Flavour; dairy or non-dairy; brand name; luxury/premium; added nuts, fruit*	• Number of spoons – choose spoon size in photo 20 • Estimate amount with photo 8
Jam, honey, marmalade	*What sort; type and brand; low-sugar/diabetic; thick-cut; shop bought/homemade*	• Number of spoons – choose spoon size in photo 20 • Spread thin/medium/thick
Meat (see also bacon, burgers & sausages)	*What sort; cut of meat e.g. chop, breast, minced; lean or fatty; fat removed or eaten; skin removed or eaten; how cooked; with or without gravy*	• Estimate amount with photo 18 (sausages); photo 13 (sliced meat) • Number of spoons e.g. mince – choose spoon size in photo 20
Milk	*Brand and type (whole, semi-skimmed, skimmed); fresh, sterilized, UHT, dried; soya milk (sweetened/unsweetened), goats' milk, rice milk; flavoured; fortified with added vitamins and/or minerals*	• Volume in fl oz / ml
Nuts	*What sort and brand; dry roasted, ordinary salted, honey roasted; unsalted*	• Weight and/or portion of a single packet e.g ¼ of 100g packet • Number of whole nuts or packets (with weight of packet)
Pie (sweet or savoury)	*What sort and brand; individual or helping; one pastry crust or two; type of pastry*	• Weight of whole pie and/or slice e.g. ¼ of 200g pie
Pizza	*Thin base or deep pan or French bread; topping; brand name and type*	• Weight of whole pizza and/or slice e.g. $^{1}/_{8}$ of 190g pizza • Estimate size of pizza with photo 19
Porridge	*Brand name; made with oats or cornmeal or instant oat cereal; made with milk and/or water; with sugar or honey; with milk or cream*	• Number of spoons of dry oats – choose spoon size in photo 20 • Number of packets (including weight) • Volume of milk/water added fl oz/ml
Potatoes (see also chips)	*Old or new; baked, boiled, roast (type of oil/fat); skin eaten; mashed (with butter/spread and with or without milk); fried/chips (type of oil/fat); instant; any additions e.g. butter*	• Estimate amount with photo 5 (chips), 10 (boiled/roast) • Number of spoons e.g. mash – choose spoon size in photo 20

Appendix 3.16 Seven year portion guide

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Food and portion guide

8. Ice-cream

9. Mixed vegetables

10. Potatoes

11. Pasta

CHAPTER 5

Appendix 5.1. Invitation letter for telephone interview

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DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

INFORMATION SHEET

Gemini – health and development in twins

GEM [family ID]

Dear [mother's name],

My name is Hayley Syrad and I am a PhD student working on the Gemini study. You may remember me from my interview for the last newsletter - I am looking into how children's diets are influenced by their early life experiences.

I would like to invite you to participate in a short interview about your experiences of formula feeding.

You kindly completed the Gemini diet diaries when your twins were approximately 20 months of age. The final coding of the diet diaries is now complete. We are particularly interested in the transition between formula-feeding and solids, and would like to understand more about the period during which children are given both formula milk (or follow-on milk), as well as solids. I will be interviewing 20-30 families either in their homes or over the telephone (as preferred) to discuss feeding decisions during this time in more detail.

Interviews will last approximately 20 minutes, and if you are willing, the interview will be tape-recorded. The interviews will be written up shortly afterwards and the recordings will then be deleted. The written information from the interviews will be anonymous and will not be saved with any identifiable information.

It is up to you to decide whether or not to take part in this interview. You are free to withdraw at any time during the interview and do not need to give us a reason. Any information you share will be kept confidential by the Gemini team and you will not have to answer any questions that you do not want to.

If you are willing to take part, please email me at gemini@ucl.ac.uk or telephone me on 02076 791723.

Best wishes,

Hayley Syrad

Health Behaviour Research Centre
University College London
1-19 Torrington Place
London WC1E 6BT

Tel: 020 7679 1723 Email: h.syrad@ucl.ac.uk

All data will be collected and stored in accordance with the Data Protection Act 1998.
Study Reference: 07/H0714/116
Name of Researchers: *Professor Jane Wardle, Dr. Ellen van Jaarsveld, Hayley Syrad*
Date:
Signature of Principal investigator: Jane Wardle

Appendix 5.2. Interview schedule

1) After the age of 18 months, were you giving formula milk/follow on milk to one or both of your twins?

2) Can I ask what your reasons were for giving your child(ren) formula milk at that time?

Prompts:

Worried about your child's weight?

Poor appetite?

Used to soothe/calm child?

Recommended by someone?

Used instead of cow's milk? If so why?

Contains extra nutrients?

3) How did you decide how much formula to give your child(ren)?

4) How did you decide how often to give formula to your child(ren)?

5) Can you remember when you used to give your child(ren) formula – specific times of day/routine? Why?

6) Are you still giving (Twin 1/Twin2/both) any kind of formula?

- If not what age did you stop? Why?
- If yes – why? How often?

7) How would you describe (Twin 1/Twin 2) current appetite?

8) Do you have any concerns regarding (Twin 1/Twin 2) current diet?

Appendix 5.3. Coding frame

	Supplemented diet	Used to soothe child	Recommendations	Unable to drink cow's milk	Provides nutrients	Worried about child's weight
1	X			X	X	X
2						X
3	X			X	X	X
4			X			
5	X	X	X	X	X	X
6	X				X	X
7	X	X				
8	X		X		X	
9	X			X		
10	X				X	X
11			X		X	
12	X				X	X
13	X					
14	X		X			
15			X			
16		X			X	
17		X		X	X	
18			X		X	
19				X		
20					X	
21	X	X			X	
22	X					
23	X					X
24	X			X		
25		X				

26		X			X	
27	X	X				X
28	X	X			X	X
29	X		X			
30	X				X	
31				X		
32			X			
33	X					
34		X				
35	X					
Total	**21**	**10**	**9**	**8**	**16**	**10**

CHAPTER 7

Appendix 7.1 Consumption patterns and adiposity at two years of age (*n*= 1939)

		Weight (g)[a]		**Weight SDS**[a]	
Eating patterns	**Model**	*B* (SE *B*)	*p*-value[b]	*B* (SE *B*)	*p*-value[c]
Meal size (kJ)[d]					
Consumption occasions	Separate models[e]	65 (20)	**0.001**	0.05 (0.02)	**0.001**
	Mutual adjustment models[f]	163 (28)	**<0.001**	120 (0.02)	**<0.001**
Drinking occasions	Separate models[e]	80 (20)	**<0.001**	0.06 (0.02)	**<0.001**
	Mutual adjustment models[f]	82 (20)	**<0.001**	0.06 (0.02)	**<0.001**
Meal frequency (times/day)					
Consumption occasions	Separate models[e]	36 (26)	0.16	0.03 (0.02)	0.18
	Mutual adjustment models[f]	168 (36)	**<0.001**	0.12 (0.03)	**<0.001**
Drinking occasions	Separate models[e]	69 (37)	0.06	0.05 (0.03)	0.06
	Mutual adjustment models[f]	51 (42)	0.22	0.04 (0.03)	0.22

Abbreviations: *B*, unstandardized coefficient; SE, standard error; SDS, Standard Deviation Score, kJ; kilojoules

[a] Analyses have been adjusted for sex, gestational age, birth weight, difference in age between diet diary completion and weight measurement as potential confounders

[b] p-value for associations between two year weight and consumption patterns. Significant associations ($p < 0.01$) are shown in bold.

[c] p-value for associations between two year weight SDS and consumption patterns. Significant associations ($p < 0.01$) are shown in bold.

[d] B coefficient has been re-scaled by multiplying by 100 (per 100 kJ); for each 100 kJ increase in meal size (per consumption occasion) a child's weight at two years would be 65g higher

[e] The separate model for meal size includes the meal size variable only, and the separate models for meal frequency include the meal frequency variable only

[f] The mutual adjustment model includes meal size and meal frequency variables together

Appendix 7.2 Consumption patterns and adiposity at two years of age for children with 'plausible' intakes only (*n*= 1445)

		Weight (g)[a]		**Weight SDS**[a]	
Eating patterns	**Model**	*B* (SE *B*)	*p*-value[b]	*B* (SE *B*)	*p*-value[c]
Meal size (kJ)[d]					
Consumption occasions	Separate models[e]	112 (24)	**<0.001**	0.08 (0.02)	**<0.001**
	Mutual adjustment models[f]	414 (39)	**<0.001**	0.30 (0.03)	**<0.001**
Eating occasions	Separate models[e]	97 (20)	**<0.001**	0.07 (0.03)	**<0.001**
	Mutual adjustment models[f]	181 (25)	**<0.001**	0.13 (0.02)	**<0.001**
Drinking occasions	Separate models[e]	98 (22)	**<0.001**	0.08 (0.02)	**<0.001**
	Mutual adjustment models[f]	100 (22)	**<0.001**	0.08 (0.02)	**<0.001**
Meal frequency (times/day)					
Consumption occasions	Separate models[e]	29 (26)	0.26	0.02 (0.02)	0.30
	Mutual adjustment models[f]	410 (43)	**<0.001**	0.30 (0.03)	**<0.001**
Eating occasions	Separate models[e]	-0.06 (39)	0.87	-0.007(0.03)	0.82
	Mutual adjustment models[f]	241 (49)	**<0.001**	0.17 (0.04)	**<0.001**
Drinking occasions	Separate models[e]	64 (38)	0.10	0.05 (0.03)	0.10
	Mutual adjustment models[f]	45 (43)	0.30	0.03 (0.03)	0.28

Abbreviations: *B*, unstandardized beta coefficient; SE, standard error; SDS, Standard Deviation Score, kJ; kilojoules

[a] Analyses have been adjusted for sex, gestational age, birth weight, difference in age between diet diary completion and weight measurement as potential confounders

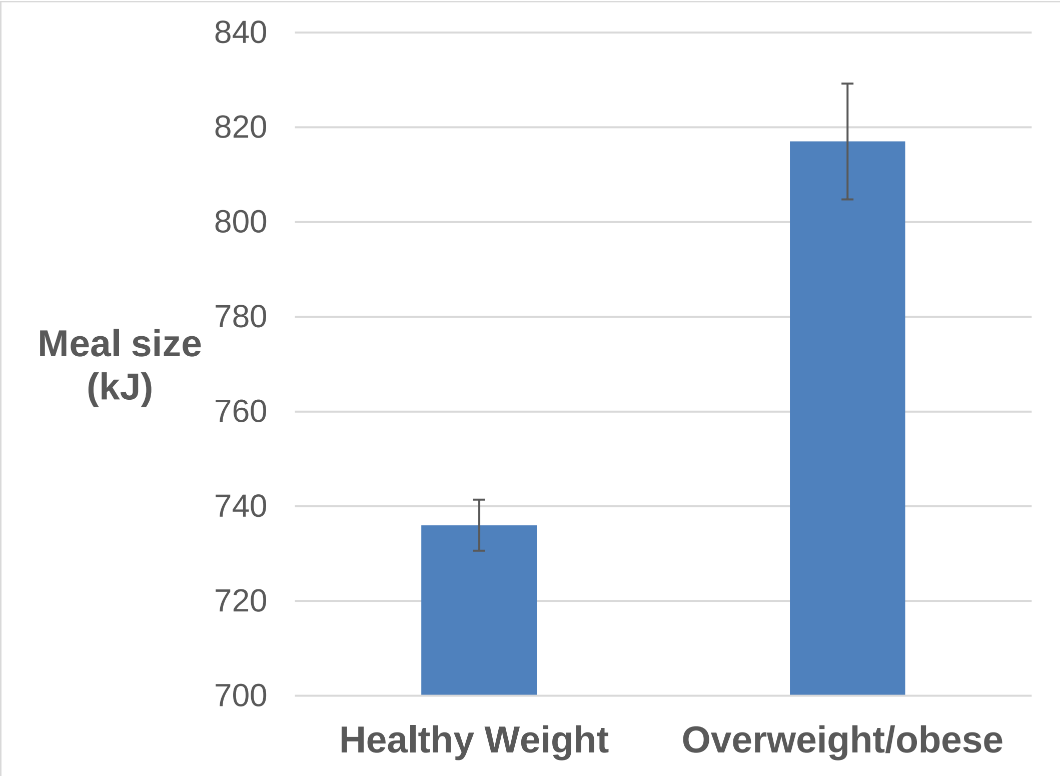
[b] p-value for associations between two year weight and consumption patterns. Significant associations ($p< 0.01$) are shown in bold.
[c] p-value for associations between two year weight SDS and consumption patterns. Significant associations ($p< 0.01$) are shown in bold.
[d] B coefficient has been re-scaled by multiplying by 100 (per 100 kJ); for each 100 kJ increase in meal size (per consumption occasion) a child's weight at two years would be 112g higher.
[e] The separate model for meal size includes the meal size variable only, and the separate models for meal frequency include the meal frequency variable only.
[f] The mutual adjustment model includes meal size and meal frequency variables together.

Appendix 7.3 Meal size and meal frequency by weight status at two[a] and five[b] years of age for children with ‘plausible’ intakes only

Consumption pattern	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value[c]**
Two years of age (*n*=1445)										
Meal size (kJ)	749 (189)	275	1461	**736** (187)	275	1461	**817** (188)	415	1452	**<0.001**
Meal frequency	5.0 (0.9)	2.7	9.7	5.0 (0.9)	2.7	9.7	5.0 (1.0)	2.7	8.0	0.59
Five years of age (*n*=1194)										
Meal size (kJ)	751 (186)	279	1461	747 (183)	2797	1461	801 (213)	368	1381	0.03
Meal frequency (times per day)	5·0 (0.9)	2.7	8.3	5.0 (0.9)	2.7	8.3	4·8 (1.0)	3·0	8.3	0.19

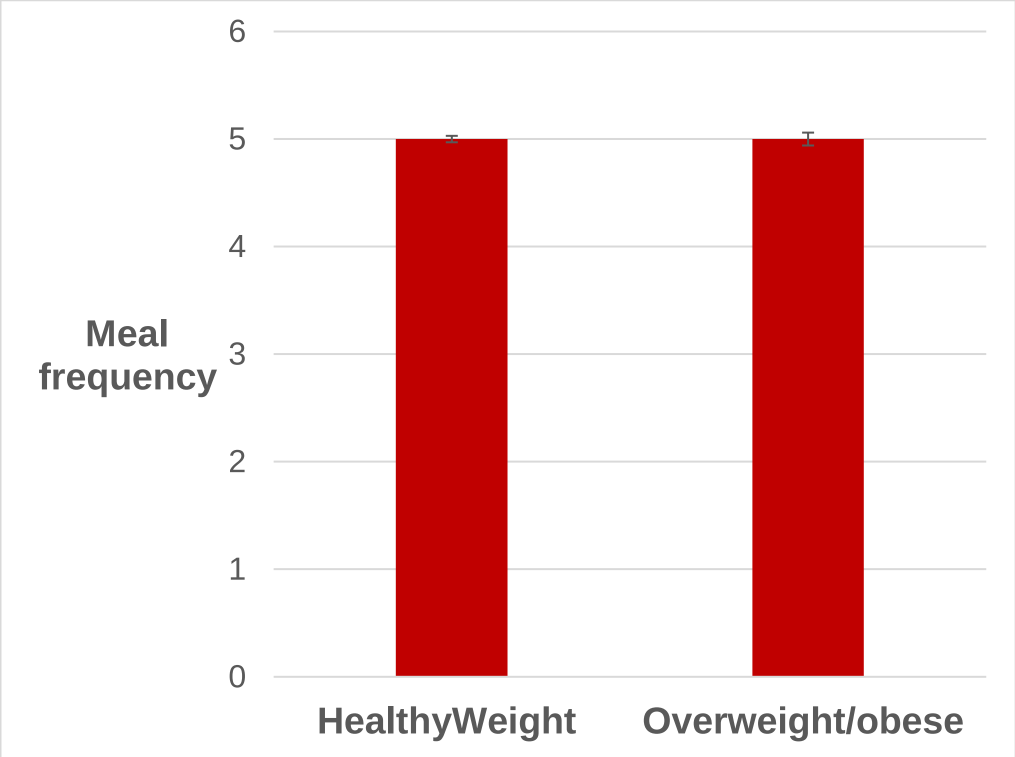
Abbreviations: SD, standard deviation; kJ, kilojoules
[a] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 237) or healthy weight (*n*= 1208) relative to the UK population mean in 1990, for the child’s age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS ≥1.04 which equates to scores at or above the 85th percentile and healthy weight as weight SDS <1.04; below the 85th percentile.
[b] Weight status at five years of age was derived using BMI standard deviation scores (SDS). Children were classified as overweight (*n*= 86) or healthy weight (*n*= 1108) relative to the UK population mean in 1990, for the child’s age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a BMI SDS ≥1.04 which equates to scores at or above the 85th percentile and healthy weight as a SDS< 1.04.
[c] Univariate Complex Samples Linear Models (CSGLMs) tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (*p*-value <0.01) are shown in bold.

Appendix 7.4 Mean scores for meal size (kJ per eating occasion) at 21 months of age partitioned according to weight status at two years of age for children with 'plausible' intakes only (*n*= 1445)



Weight status was derived using weight standard deviation scores (SDS). Overweight (*n*= 237) was classified as a weight SDS ≥1.04 (at or above the 85th percentile), and healthy weight (*n*= 1208) as SDS<1.04 (Cole et al. 1995). An eating occasion refers to an occasion in which food was consumed (and drinks if consumed with food).

Appendix 7.5 Mean scores for meal frequency (number of eating occasions) at 21 months of age partitioned according to weight status at two years of age for children with 'plausible' intakes only (*n*= 1445)



Weight status was derived using weight standard deviation scores (SDS). Overweight (*n*= 237) was classified as a weight SDS ≥1.04 (at or above the 85th percentile), and healthy weight (*n*= 1208) as SDS<1.04 (Cole et al. 1995). An eating occasion refers to an occasion in which food was consumed (and drinks if consumed with food).

Appendix 7.6 Odds of being overweight compared to healthy weight at two years of age according to meal size and meal frequency for children with 'plausible' intakes only (*n*= 1445)

		Odds of overweight[a]	
Consumption pattern	**Model**	**OR (95% CI)**	***p*-value[e]**
Meal size	1[b]	1.24 (1.14; 1.33)	**<0.001**
(100 kJ per eating occasion)	2[c]	1.20 (1.11; 1.31)	**<0.001**
	3[d]	1.40 (1.25; 1.57)	**<0.001**
Meal frequency	1[b]	0.95 (0.80; 1.14)	0.59
(eating occasions per day)	2[c]	0.94 (0.78; 1.15)	0.56
	3[d]	1.55 (1.21; 2.00)	**0.001**

Abbreviations: OR, Odds Ratio; CI, Confidence Interval; kJ, kilojoules

[a] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 237) or healthy weight (*n*= 1208) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as weight SDS ≥ 1.04 which equates to scores at or above the 85th percentile, and healthy weight as SDS< 1.04.

[b] Model 1: Univariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were unadjusted for covariates.

[c] Model 2: Multivariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, gestational age, birth weight, difference between age at diet diary completion and weight measurement.

[d] Model 3: Multivariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, gestational age, birth weight, difference between age at diet diary completion, weight measurement and mutually adjusted for each meal parameter.

[e] Significant associations (p< 0.01) are shown in bold.

Appendix 7.7 Odds of being overweight compared to healthy weight at five years of age according to meal size and frequency for children with 'plausible' intakes only (*n*= 1194)

		Odds of overweight[a]	
Consumption pattern	**Model**	**OR (95% CI)**	**P value**
Meal size	1[b]	1.16 (1.01;1.32)	0.03
(100 kJ per eating occasion)	2[c]	1.07 (0.92;1.24)	0.38
	3[d]	1.01 (0.80;1.26)	0.96
Meal frequency	1[b]	0.83 (0.62;1.10)	0.19
(eating occasions per day)	2[c]	0.83 (0.62;1.10)	0.20
	3[d]	0.83 (0.54;1.28)	0.41

Abbreviations: OR, Odds Ratio; CI, Confidence Interval; kJ, kilojoules

[a] Weight status at five years of age was derived using BMI standard deviation scores (SDS). Children were classified as overweight (*n*= 86) or healthy weight (*n*= 1108) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a BMI SDS≥ 1.04 which equates to scores above the 85th percentile, and healthy weight as SDS< 1.04.

[b] Model 1: Univariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were unadjusted for covariates.

[c] Model 2: Multivariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, gestational age, birth weight, difference between age at diet diary completion and weight measurement, and weight at two years of age.

[d] Model 3: Multivariate complex samples logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, gestational age, birth weight, difference between age at diet diary completion and weight measurement, weight at two years of age and mutually adjusted for each meal parameter.

Appendix 7.8 Daily energy intake and meal composition by weight status[a] at two years for children with 'plausible' intakes only

	Full sample (*n*= 1445)			**Healthy weight** (*n*= 1208)			**Overweight** (*n*= 237)			
Consumption pattern	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Daily energy intake (kJ per day)	4331 (518)	2858	6055	**4260** (498)	2858	5870	**4689** (471)	3664	6055	**<0.001**
Meal composition										
Meal weight (g)	191 (60)	36	401	**187 (59)**	36	395	**211** (64)	75	401	**<0.001**
Meal energy density (kJ/g)[c]	4.1 (0.9)	1.9	8.7	4.1 (0.9)	1.9	8.7	4.0 (0.9)	2.0	6.7	0.37
Protein per meal (%mE)	11.8 (1.8)	6.2	21.1	11.8 (1.7)	6.1	21.1	11.9 (1.7)	8.0	16.8	0.91
Carbohydrate per meal (%mE)	54.8 (6.1)	35.5	77.3	54.8 (6.1)	35.5	73.2	54.5 (6.0)	41.3	77.3	0.51
Fat per meal (%mE)	33.4 (5.2)	13.4	55.8	33.4 (5.2)	17.4	64.5	33.6(5.0)	13.4	48.9	0.48

Abbreviations: SD, standard deviation; kJ, kilojoules; g, grams; kJ/g, kilojoules per gram; %mE, percentage of meal energy

[a] Weight status at two years of age was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 237) or healthy weight (*n*= 1208) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS≥ 1.04 which equates to scores at or above the 85^{th} percentile, and healthy weight as weight SDS<1.04; below the 85^{th} percentile.

[b] Univariate Complex Samples Linear Regression Models (CSGLMs) tested for significance of mean difference between healthy weight and overweight children for each meal parameter. Significant differences (*p*-value <0.01) are shown in bold.

[c] Results are largely unchanged by calculating energy density of food only (excluding the contribution of drinks to the weight of each meal) (*p*= 0.92).

Appendix 7.9 Daily energy intake and meal composition by weight status[a] at five years for children with ‘plausible’ intakes only (*n*=1194)

	Full sample (*n*= 1194)			**Healthy weight** (*n*= 1108)			**Overweight** (*n*= 86)			
Meal parameter	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Daily energy intake (kJ per day)	4328 (511)	683	1447	**4309 (501)**	2858	6015	**4576 (578)**	3429	6054	**0.001**
Meal composition										
Meal weight (g)	190 (58)	68	401	189 (57)	74	401	204 (62)	68	353	0.06
Meal energy density (kJ/g) [c]	4.1 (0.9)	1.9	8.7	4.1 (0.8)	1.9	7.8	4.1 (1.1)	2.1	8.7	0.86
Protein per meal (%mE)	11.9 (1.7)	6.2	21·1	11.9 (1.7)	6.2	21.1	11.8 (1.6)	8.2	16.0	0.54
Carbohydrate per meal (%mE)	54·6 (5.8)	36.8	77.3	54.6 (5.7)	36.8	77.3	54.5 (6.6)	41.3	69.8	0.93
Fat per meal (%mE)	33·5 (4.9)	13.4	55.8	33.5 (4.8)	13.4	55.8	33.7 (5.9)	20.0	45.7	0.79

Abbreviations: SD, standard deviation; kJ, kilojoules; g, grams; kJ/g, kilojoules per gram; %mE, percentage of meal energy

[a] Weight status at five years of age was derived using BMI standard deviation scores (SDS). Children were classified as overweight (*n*= 86) or healthy weight (*n*= 1108) relative to the UK population mean in 1990, for the child’s age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a BMI SDS ≥1.04 which equates to scores at or above the 85th percentile, and healthy weight as a SDS <1.04.

[b] Univariate Complex Samples Linear Regression Models (CSGLMs) tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (*p*-value <0.01) are shown in bold.

[c] Results are largely unchanged by calculating energy density of food only (excluding the contribution of drinks to the weight of each meal) (*p*= 0.46).

Appendix 7.10 Consumption patterns and adiposity for children aged four to 18 months in the DNSIYC (*n*=2564)

		Weight (g)[a]		**Weight SDS**[a]	
Eating patterns	**Model**	*B* (SE *B*)	*p*-value[b]	*B* (SE *B*)	*p*-value[c]
Meal size (kJ)[d]					
Consumption occasions	Separate models[e]	95 (15)	**<0.001**	0.08 (0.01)	**<0.001**
	Mutual adjustment models[f]	131 (19)	**<0.001**	0.11 (0.02)	**<0.001**
Drinking occasions	Separate models[e]	112 (14)	**<0.001**	0.10 (0.01)	**<0.001**
	Mutual adjustment models[f]	107 (15)	**<0.001**	0.09 (0.01)	**<0.001**
Meal frequency (times/day)					
Consumption occasions	Separate models[e]	-20 (11)	0.06	0.02 (0.01)	0.02
	Mutual adjustment models[f]	131 (19)	**0.004**	0.03 (0.01)	0.02
Drinking occasions	Separate models[e]	-41 (13)	**0.001**	-0.04 (0.01)	**0.001**
	Mutual adjustment models[f]	-20 (13)	0.11	-0.02 (0.01)	0.10

Abbreviations: DNSIYC, Diet and Nutrition Survey for Infants and Young Children; g, grams; SDS, Standard Deviation Score; *B*, unstandardized coefficient; SE, standard error; kJ, kilojoules

[a] Analyses have been adjusted for sex, age and birth weight as potential confounders

[b] p-value for associations between weight and consumption patterns. Significant associations ($p < 0.01$) are shown in bold.

[c] p-value for associations between weight SDS and consumption patterns. Significant associations ($p < 0.01$) are shown in bold.

[d] *B* coefficient has been re-scaled by multiplying by 100 (per 100 kJ); for example, for each 100 kJ increase in meal size (per consumption occasion) a child's weight would be 95g higher

[e] The separate model for meal size includes the meal size variable only, and the separate models for meal frequency include the meal frequency variable only

[f] The mutual adjustment model includes meal size and meal frequency variables together

Appendix 7.11 Consumption patterns and adiposity for children aged four to 18 months in the DNSIYC with 'plausible' intakes only (*n*=1612)[a]

		Weight (g)[a]		**Weight SDS**[a]	
Eating patterns	**Model**	*B* (SE *B*)	*p*-value[b]	*B* (SE *B*)	*p*-value[c]
Meal size (kJ)[d]					
Consumption occasions	Separate models[e]	168 (19)	**<0.001**	0.14 (0.02)	**<0.001**
	Mutual adjustment models[f]	463 (33)	**<0.001**	0.20 (0.02)	**<0.001**
Eating occasions	Separate models[e]	112 (15)	**<0.001**	0.09 (0.01)	**<0.001**
	Mutual adjustment models[f]	159 (17)	**<0.001**	0.13 (0.01)	**<0.001**
Drinking occasions	Separate models[e]	130 (17)	**<0.001**	0.11 (0.02)	**<0.001**
	Mutual adjustment models[f]	124 (18)	**<0.001**	0.11 (0.02)	**<0.001**
Meal frequency (times/day)					
Consumption occasions	Separate models[e]	-18 (13)	0.18	-0.02 (0.01)	0.14
	Mutual adjustment models[f]	243 (23)	**<0.001**	0.39 (0.03)	**<0.001**
Eating occasions	Separate models[e]	46 (23)	0.05	0.03 (0.02)	0.10
	Mutual adjustment models[f]	156 (26)	**<0.001**	0.12 (0.02)	**<0.001**
Drinking occasions	Separate models[e]	-0.046 (0.016)	**0.004**	-0.04 (0.01)	**0.005**
	Mutual adjustment models[f]	-0.023 (0.016)	0.16	-0.02 (0.01)	0.20

Abbreviations: DNSIYC, Diet and Nutrition Survey for Infants and Young Children; g, grams; SDS, Standard Deviation Score; *B*, unstandardized coefficient; SE, standard error; kJ, kilojoules

[a] Analyses have been adjusted for sex, age and birth weight as potential confounders

[b] p-value for associations between weight and consumption patterns. Significant associations ($p < 0.01$) are shown in bold.

[c] p-value for associations between weight SDS and consumption patterns. Significant associations (*p*< 0.01) are shown in bold.
[d] *B* coefficient has been re-scaled by multiplying by 100 (per 100 kJ); for each 100 kJ increase in meal size (per consumption occasion) a child's weight would be 168g higher
[e] The separate model for meal size includes the meal size variable only, and the separate models for meal frequency include the meal frequency variable only
[f] The mutual adjustment model includes meal size and meal frequency variables together

Appendix 7.12 Meal size and frequency by weight status[a] for children aged four to 18 months in the DNSIYC, with 'plausible' intakes only

	Full sample (*n*= 1612)			**Healthy weight** (*n*= 1072)			**Overweight** (*n*= 540)			
Meal parameter	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Meal size (kJ per eating occasion[a])	589 (191)	10	1399	**566 (190)**	10	1399	**636 (186)**	69	1308	**<0.001**
Meal frequency (eating occasions[a] per day)	4.7 (1.3)	0.3	10.8	**4.6 (1.3)**	0.3	10.8	**4.9 (1.3)**	1.0	10.3	**<0.001**

Abbreviations: SD, standard deviation; kJ, kilojoules

[a] Weight status was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 540) or healthy weight (*n*= 1072) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS≥ 1.04 which equates to scores at or above the 85th percentile, and healthy weight as weight SDS< 1.04; below the 85th percentile.

[b] Independent t-tests tested for significance of mean difference between healthy weight and overweight children for each meal parameter; significant differences (*p*-value <0.01) are shown in bold.

Appendix 7.13 Odds of being overweight compared to healthy weight according to meal size and frequency for children aged four to18 months in the DNSIYC, with 'plausible' intakes only (*n*= 1612)

		Odds of overweight[a]	
Consumption pattern	**Model**	**OR (95% CI)**	***p*-value[b]**
Meal size	1[c]	1.22 (1.15;1.29)	**<0.001**
(100 kJ per eating occasion)	2[d]	1.18 (1.11;1.25)	**<0.001**
	3[e]	1.30 (1.21;1.40)	**<0.001**
Meal frequency	1[c]	1.16 (1.07;1.26)	**<0.001**
(eating occasions per day)	2[d]	1.08 (0.98;1.18)	0.12
	3[e]	1.32 (1.18;1.48)	**<0.001**

Abbreviations: OR, Odds Ratio; kJ, kilojoules; CI, Confidence Interval

[a] Weight status was derived using BMI standard deviation scores (SDS). Children were classified as overweight (*n*= 540) or healthy weight (*n*= 1072) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a BMI SDS≥ 1.04 which equates to scores at or above the 85th percentile, and healthy weight as a SDS< 1.04.

[b] Significant associations ($p < 0.01$) are shown in bold.

[c] Model 1: Logistic regression analyses tested the odds of being healthy weight versus

[d] Model 2: Logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, birth weight, and age

[e] Model 3: Logistic regression analyses tested the odds of being healthy weight versus overweight for higher levels of each meal parameter. Models were adjusted for sex, birth weight, and age and mutually adjusted for each meal parameter.

Appendix 7.14 Daily energy intake and meal composition by weight status[a] for children aged four to 18 months in the DNSIYC, with 'plausible' intakes only

	Full sample (*n*= 1612)			**Healthy weight** (*n*= 1072)			**Overweight** (*n*= 540)			
Consumption pattern	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	***p*-value**[b]
Daily energy intake (kJ per day)	3851 (561)	2845	5640	**3712 (252)**	2485	5073	**4126 (528)**	2929	5640	**<0.001**
Meal composition										
Meal weight (g)	157 (58)	3	361	**151 (57)**	3	358	**169 (57)**	35	361	**<0.001**
Meal energy density (kJ/g)	3.9 (0.9)	1.6	15.3	3.9 (1.0)	1.6	15.3	3.9 (0.9)	1.9	8.0	0.86
Protein per meal (%mE)	12.2 (2.2)	4.3	24.1	**12.0 (2.3)**	4.3	22.6	**12.5 (2.2)**	4.8	24.1	**0.001**
Carbohydrate per meal (%mE)	57.4 (7.3)	31.7	95.2	**57.7 (7.7)**	31.7	87.9	**56.7 (6.6)**	35.2	95.2	**0.005**
Fat per meal (%mE)	30.4 (6.2)	4.8	58.2	30.3 (6.5)	6.8	58.2	30.8 (5.5)	4.8	47.0	0.11

Abbreviations: SD, standard deviation; kJ, kilojoules; g, grams, kJ/g, kilojoules per gram; %mE, percentage of meal energy

[a] Weight status was derived using weight standard deviation scores (SDS). Children were classified as overweight (*n*= 540) or healthy weight (*n*= 1072) relative to the UK population mean in 1990, for the child's age, sex, and gestational age (Cole et al. 1995). Overweight was classified as a weight SDS≥ 1.04 which equates to scores at or above the 85th percentile, and healthy weight as weight SDS< 1.04; below the 85th percentile.

[b] Independent t-tests tested for significance of mean difference between healthy weight and overweight children for each meal parameter. Significant differences (*p*-value< 0.01) are shown in bold.

CHAPTER 9

Appendix 9.1 The Child Eating Behaviour Questionnaire (CEBQ) – seven year version

APPETITE
These questions are about the twins' appetites

How would you describe your twins' eating styles on a typical day?

			Never	Rarely	Sometimes	Often	Always
1.	**My child loves food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
2.	**My child has a big appetite**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
3.	**My child finishes his/her meal quickly**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
4.	**My child is interested in food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
5.	**My child refuses new foods at first**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
6.	**My child eats slowly**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
7.	**My child enjoys tasting new foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
8.	**My child is always asking for food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
9.	**If allowed to, my child would eat too much**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
10.	My child enjoys a wide variety of foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
11.	My child leaves food on his/her plate at the end of a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
12.	My child takes more than 30 minutes to finish a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
13.	Given the choice, my child would eat most of the time	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
14.	My child looks forward to mealtimes	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
15.	My child gets full before his/her meal is finished	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
16.	My child enjoys eating	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
17.	My child is difficult to please with meals	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
18.	My child gets full up easily	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
19.	Even if my child is full up he/she finds room to eat his/her favourite food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
20.	My child cannot eat a meal if he/she has had a snack just before	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
21.	My child is interested in tasting food he/she hasn't tasted before	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
22.	My child decides that he/she doesn't like a food without even tasting it	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
23.	If given the chance my child would always have food in his/her mouth	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
24.	My child eats more and more slowly during the course of a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐