Toddler Food and Activity Patterns and Body Composition: A Study of the Offspring of Mothers Treated for Gestational Diabetes

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ATTESTATION OF AUTHORSHIP

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other research institution of higher learning"

Signed:…………………………..

Date:…………………………….

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ABSTRACT

Accumulation of excess body fat tracks from an early age and interventions aimed at preventing childhood obesity may need to begin early in life, particularly for children exposed to gestational diabetes mellitus (GDM). There is evidence from animal studies food and activity patterns in offspring may be programmed by an adverse intrauterine environment, however evidence of an effect in humans is lacking. The ethnic diversity of young people in New Zealand is increasing but little is known with respect to the early life ethnic differences in food and activity patterns and body composition. Understanding differences may help explain the genesis of ethnic disparity in the prevalence of obesity and associated health conditions

The primary aim of this study was to examine and compare food and activity patterns and body composition in a sample of 147 children at the mid-toddler stage of development. The average age was 27.7 months and 48 European (F 26; M 28), 41 Polynesian (F 22; M 19), 36 Indian (F 17; M 19), 18 Asian (F 12; M 6) and 4 Other (F 3; M 1) children were studied. Because the children in this study were born to mothers treated for GDM, the effects of maternal glucose control and GDM treatment (metformin versus insulin) on food and activity patterns were also examined.

Food and activity data were collected by a food frequency questionnaire, 24-hour food recall and a 24-hour activity recall. Body composition was measured using anthropometry, bioimpedance analysis (BIA) and dual-energy x-ray absorptiometry (DEXA) when possible. DEXA scans were used to validate a BIA equation to predict fat free mass.

When compared with the Ministry of Health (MoH) nutritional guidelines, two-thirds of toddlers did not consume breads and cereals four or more time per day, and one-third and one-quarter did not consume fruit and vegetables twice a day respectively. Three-quarters of toddlers consumed treat foods at least once a day, and takeaways at least twice a week and more than two-thirds consumed sweet drinks at least once a day. Toddlers slept on average 12.5 hours per 24 hour period, watched 1.0 hour of television, and played actively for almost 5.0 hours. Overall girls had a higher fatness

(3%) than boys. No associations between food and activity patterns and body composition at 2 years of age were found, and no associations between maternal glucose control, GDM treatment (metformin versus insulin) or food and activity patterns at 2 years of age were found.

Marked ethnic differences in food and activity patterns and body composition were found. Specifically:

- Less Indian children consumed fruit twice a day and meat once a day than European children, and more Polynesian children consumed takeaways at least five times a week than European children.
- Polynesian, Asian and Indian toddlers slept for 1.0 hour less than European toddlers and watched around 0.5 hours more television per day.
- Polynesian toddlers were taller and heavier than other ethnic groups and had on average 2% more body fat than European toddlers.
- After adjusting for height, weight and age, Indian children had on average 0.3kg more fat mass than European and Polynesian toddlers.

Overall, a notable proportion of toddlers did not consume the recommended servings of breads and cereals, fruit and vegetables per day, regularly consumed treat foods, sweet drinks and takeaways, and watched TV. Ethnic differences in food and activity patterns and body composition were identified in this study in that could contribute to the ethnic disparity in the prevalence of obesity and related diseases. With food and activity patterns and body composition shown to track from an early age, interventions aimed at preventing obesity may need to begin early in life and be sustained throughout the life course.

ABBREVIATIONS

%BF	Percentage body fat
ABC	Auckland Birth Cohort
BIA	Bioelectrical impedance analysis
BMC	Bone mineral content
BMI	Body mass index
CI	Confidence intervals
CNS	Child nutrition survey
CVD	Cardiovascular disease
DEXA	Dual energy x-ray absorptiometry
FFM	Fat free mass
FFQ	Food frequency questionnaire
FM	Fat mass
GDM	Gestational diabetes mellitus
GI	Glycaemic index
LM	Lean mass
MiG	Metformin in Gestational Diabetes
MiGTOFU	Metformin in Gestational Diabetes the Offspring Follow Up
MoH	Ministry of Health
NZ	New Zealand
OR	Odds ratio
PIF	Pacific Island Families
SD	Standard deviation
SE	Standard error
T2DM	Type 2 diabetes mellitus
TBM	Total body mass
TV	Television
WHO	World Health Organisation

GLOSSARY

Asian: people who originate from the Asian continent (in this thesis the ethnic group Asian refers to Chinese and Other Asian, but not Indian, participants).

Breads and cereals: food group which includes bread, cereal, rice, noodles, pasta, roti, chappati, naan and dumplings.

European: people who originate from Europe.

Fruit: food group which includes fresh fruit, dried fruit, tinned fruit in juice and tinned fruit in syrup

Indian: people who originate from India.

Maori: people indigenous to NZ, who originate from Polynesia.

Meat: food group which includes red meat, other meat, processed meat and fish.

Meat and other protein: food group which includes red meat, other meat, processed meat and fish, as well as eggs, lentils and beans.

Milk and dairy products: food group which contains milk, cheese and yoghurt

Other protein: food group which contains eggs, lentils and beans.

Pacific: people who originate from Polynesia, not including Maori.

Polynesian: people who originate from Polynesia, including Maori.

Preschooler: in this thesis, preschooler refers to children aged 3 to 5 years. Other studies reviewed in this thesis which refer to preschoolers include children aged from 2 to 6 years.

Snacks: refers to foods consumed between main meals.

South Asian: people who originate from India, Sri Lanka, Bangladesh and Pakistan.

Sweetened milk: refers to food drinks (e.g. Milo), milk shakes and flavoured milk

Sweet drinks: food group which includes fruit juice and sugar sweetened drinks

Sugar sweetened drinks: refers to drinks with added sugar such as cordial, fruit drinks and soft drinks, but NOT sweetened milk

Takeaways: refers to foods bought from McDonalds, Burger King, Wendy's, as well as pizza, fish and chips, Chinese takeaways and Indian takeaways

Takeaways and fries: food group which contains takeaways and fries.

Toddler: in this thesis toddler refers to children aged 1 to 3 years.

Treat foods: food group which includes biscuits, crisps, lollies, muesli bars, chocolate bars.

Vegetables: food group which includes green vegetables, red/orange vegetables, other vegetables, potatoes, kumara, taro and plantain.

Z-score: a statistical measure which indicates how many standard deviations an observation lies from the mean

CHAPTER 1: INTRODUCTION

Presented in this chapter is an introduction to the problem of childhood obesity, an outline of the study and the study population, a current literature review, and a statement of the aims and hypotheses.

1.1 The problem

In New Zealand (NZ) and around the world the prevalence of childhood obesity is increasing (Wang et al., 2006), and it is estimated that around 10% of children worldwide are overweight or obese (Lobstein et al., 2004). Obesity in childhood, as in adulthood, is associated with hypertension, dyslipidaemia, increased coagulation tendency, endothelial dysfunction, and hyperinsulinaemia (Ferguson et al., 1998; Freedman et al., 1999; Ford et al., 2001; Tounian et al., 2001; Srinivasan et al., 2002). Overweight and obesity in childhood tends to track into adulthood (Guo et al., 1999; Deshmukh-Taskar et al., 2006; Singh et al., 2008), placing obese children at an increased risk of obesity related diseases such as cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM) later in life (Reilly et al., 2003).

Though high levels of childhood overweight and obesity are observed across all populations in developed and many developing countries, ethnic disparity exists in the prevalence of overweight and obesity. Based on body mass index (BMI) definitions, the prevalence of obesity in the 2006/2007 NZ Health Survey was higher among Pacific and Maori children aged 5 to 14-years (23.3% and 11.8% respectively) compared with NZ European and Asian (5.5% and 5.9% respectively)(Ministry of Health, 2008b). These figures may underestimate the prevalence of obesity in Indian and other Asian ethnic groups, who have more body fat for a given height and weight than European (Deurenberg et al., 2002) , and may therefore be at risk of obesity related diseases at relatively low BMI values. In NZ the prevalence of diagnosed T2DM is higher among Pacific, Maori and Asian (including Indian) adults than adults in the total population (Ministry of Health, 2008b).

The ethnic diversity of NZ is increasing, with Asian (including Indian), Pacific and Maori projected to have the greatest population growth in the upcoming years (Statistics New Zealand, 2008). The excess prevalence of obesity and T2DM among these ethnic groups therefore needs to be addressed. Effective interventions will require an understanding of the pathogenesis of childhood obesity, and how risk factors vary among ethnic groups.

1.1.1 The pathogenesis of childhood obesity

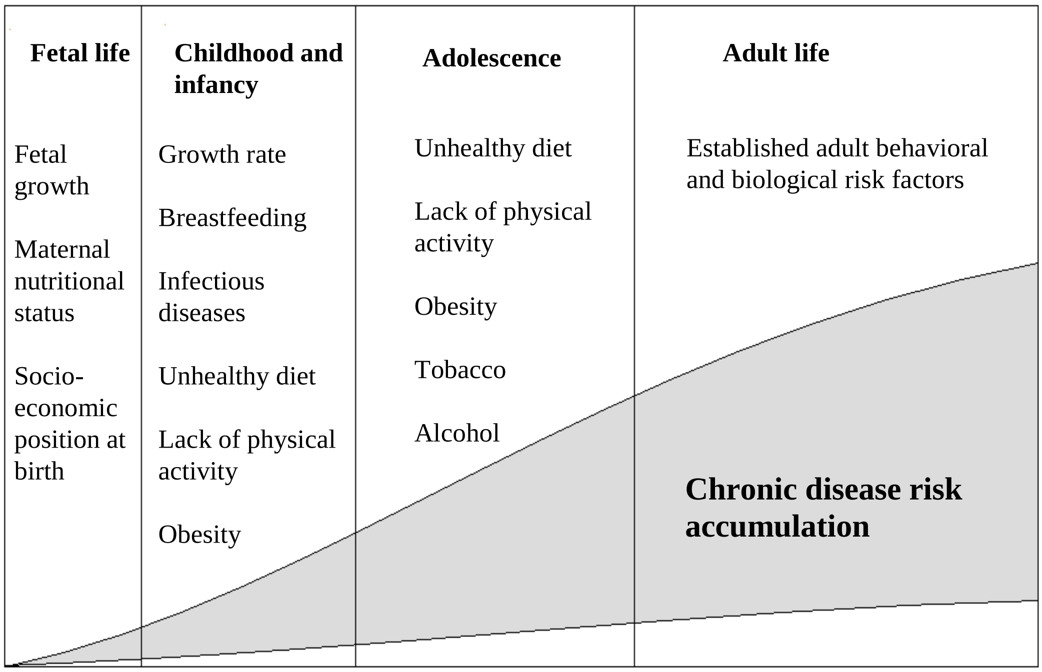
Though the pathogenesis of obesity is not yet fully understood, it is thought to involve complex interactions between an individual's genetic background and environment (Spiegelman et al., 2001). The prevalence of obesity has continued to rise in genetically stable populations illustrating the importance of environmental factors, such as the food supply and opportunities for physical activity, in promoting obesity. The rapid rise in obesity that has occurred over the past few decades is associated with a shift in food and activity patterns towards the consumption of energy -dense, nutrient-poor foods and increasingly sedentary lifestyles (World Health Organisation, 2000; Popkin et al., 2001). Traditional and ethnic diets, high in complex carbohydrates and fibre, are being increasingly replaced with Western style diets high in fat, sugar and animal products (Drewnowski, 2000; Popkin, 2001).

Environmental factors alone, however, cannot explain why in a population sharing a similar environment only certain individuals will become obese. Twin studies have provided evidence of a genetic element to obesity risk (Silventoinen et al., 2009), and in a recent review, Bouchard (2009) proposes common forms of childhood obesity result from a genetic predisposition towards obesogenic behaviors in an obesogenic environment.

The relationship between genetic background and environment is further complicated by the observation that exposures at critical periods in development may lead to heritable changes in gene expression, without changing gene structure, a process known as epigenetics (Gluckman et al., 2008). As around 75% of all cell divisions take place before birth, it is not surprising that exposures during fetal life, such as maternal undernutrition or overnutrition, may influence health and disease in postnatal life.

Childhood and adulthood obesity is thus likely to result from risk factors involving an individual's genetic background, intrauterine environment (such as maternal nutritional status) and postnatal environment. This fits in with the life course model of chronic disease risk accumulation (Figure 1.1), illustrated in a report by the World Health Organisation (WHO) (Aboderin I, 2002). The life course model of chronic disease explains how an individual will accumulate risk throughout their life course, beginning in the prenatal period, which, acting on their inherited genetic predisposition will determine whether they develop chronic diseases as adults.

Figure 1.1 Life course model of chronic disease risk accumulation



Adapted from 'Life Course Perspectives on Coronary Heart Disease, Stroke and Diabetes: Key Issues and Implications for Policy and Research' by the World Health Organisation (World Health Organisation, 2002)

Infancy and early childhood has been suggested as an important, if not critical, period for obesity prevention (Reilly, 2008). Longitudinal studies suggest that the trajectories of excess weight gain may be established before the preschool period (Reilly et al., 2005a; Ekelund et al., 2006; Huus et al., 2007; Li et al., 2007), and once obesity has developed in preschoolers it tends to persist (Freedman et al., 2005; Nader et al., 2006). Furthermore, food and activity patterns may track from a young age (Pate et al., 1996; Wang et al., 2002), and an unhealthy lifestyle (such as physical inactivity) during childhood has been found to predict CVD risk later in life, regardless of whether it is maintained in adulthood (World Health Organisation, 2002).

Interventions aimed at preventing obesity may therefore need to begin in early life be sustained throughout the life course. An understanding of the genetic, intrauterine and postnatal environmental factors that promote the accumulation of excess body fat are needed. One intrauterine risk factor associated with an increased risk of childhood obesity is exposure to maternal gestational diabetes mellitus (GDM).

1.1.2 Gestational diabetes mellitus and childhood obesity

GDM is a maternal glucose intolerance first diagnosed during pregnancy (Metzger et al., 1998). The prevalence of GDM has increased by 10 to 100% in certain populations over the past 20 years, and tends to reflect the prevalence of T2DM in the underlying population (Ferrara, 2007). Ethnicity appears to be an important factor in determining GDM risk. Of women who delivered at National Women's Hospital in 2008, GDM was diagnosed in over 16% of Indian, 10% of other Asian and 6% of Pacific women, compared with only 3% of NZ European women (Auckland District Health Board, 2008).

GDM is known is to be associated with an increased risk of pregnancy complications (Kjos et al., 1999) and later T2DM for the mother (Simmons, 2009). More recently, an increased risk of obesity and T2DM in the offspring of mothers with GDM has been recognised (Plagemann et al., 1997; Vohr et al., 2008) . It is thought that exposure to maternal hyperglycaemia during critical periods in development may lead to epigenetic changes in the expression of key genes, effectively programming obesity and insulin resistance in offspring (Plagemann, 2005; Fetita et al., 2006).

What is not yet known is the importance of the prenatal environment relative to the postnatal environment in determining disease risk. There is evidence from animal studies that the prenatal nutritional environment offspring are exposed to can alter their postnatal food and activity patterns (Vickers et al., 2000; Vickers et al., 2003). Furthermore, evidence from animal studies suggests that the prenatally programmed increased risk of obesity in offspring can be attenuated by postnatal diet and activity (Gorski et al., 2006a; Miles et al., 2009b).

With obesity and advanced maternal age both risk factors for GDM (Solomon et al., 1997; Chu et al., 2007), its prevalence looks set to rise in the upcoming years. In effect a cycle could develop, where offspring born to mothers with GDM become obese and develop diabetes before their childbearing years, only to pass this on to their offspring. In order to break this cycle efforts are needed to improve the health of young women before and during pregnancy, including the diagnosis and treatment of GDM. In addition, an understanding of postnatal environmental factors such as food and activity patterns, which may modify the risk of obesity and T2DM in offspring, is needed.

1.1.3 Study overview and population

The participants examined in this study are the 2-year old offspring of mothers treated for GDM, who participated in the Metformin in Gestational Diabetes (MiG) trial during pregnancy. The MiG trial was carried out to assess metformin as an effective alternative treatment to insulin for women with GDM (Rowan et al., 2008). Metformin acts to improve insulin sensitivity and as it crosses the placenta (unlike insulin) it was hypothesised that it may have additional beneficial effects on insulin sensitivity in offspring.

The Metformin in Gestational Diabetes: the Offspring Follow Up (MiGTOFU) study is a longitudinal study which follows offspring from women who participated in the MiG trial. A feature of this study is that the cohort is multiethnic, and contains a high proportion of Pacific, Indian and Asian children as well as European children. Offspring were followed up at 2 years of age, and in addition to other measurements, food, activity and body composition data were collected.

The primary aim of the body of work contained in this thesis was to examine food and activity patterns and body composition in 2-year old NZ children. Because of the clear ethnic disparity in the prevalence of childhood obesity, ethnic differences in food and activity patterns and body composition were examined. Furthermore, because these 2-year old children were born to mothers with GDM, they are potentially at an increased risk of obesity. A secondary aim of this study was therefore to examine whether children’s food and activity patterns at 2-years of age were affected by their mothers glucose control during pregnancy. Finally, as the aim of the MiGTOFU study was to confirm metformin is a safe and effective alternative treatment to insulin for GDM (with no adverse effects on offspring postnatally), the effect of maternal treatment for GDM with metformin as opposed to insulin on food and activity patterns in offspring was examined.

Associations between maternal GDM treatment, maternal glucose control, birthweight and 2-year old body composition are being examined elsewhere and are not a part of this thesis.

1.2 Literature review

The literature review is divided into four sections. Ethnic differences in obesity and body composition are examined, followed by a review of food and activity patterns and associations with obesity. Because the children in this study were exposed to GDM during gestation, the association between exposure to GDM and childhood obesity is reviewed and evidence from animal studies linking an altered prenatal environment with postnatal food and activity patterns presented. Finally, methods of measuring food and activity patterns and body composition in children are briefly reviewed.

1.2.1 Ethnic differences in obesity

As mentioned previously, there is ethnic disparity in the prevalence of obesity and obesity related diseases, with Pacific and Maori children and adults in NZ more likely to be obese than children in the general population (Ministry of Health, 2003; Ministry of Health, 2008b); and Pacific, Maori and Asian (including Indian) adults more likely have diagnosed T2DM than adults in the general population (Ministry of Health, 2008b).

Pacific children in NZ appear to be on a trajectory of excess weight from birth. Rush et al. (2008b) reported z-scores (based on the 2006 WHO growth standards) for weight, height and BMI in a sample of 659 Pacific children at ages 0, 2 and 4 years. At birth, the average z-score for weight was 0.605. At 2 years of age, weight and BMI-for-age z-scores were 1.062 and 1.701 respectively, and at 4 years, weight and BMI-for-age z-scores were 1.688 and 1.969 respectively. Mean height z-score was lower at 2 years of age (-0.232), but higher at 4 years, (0.626). Pacific children gained on average 11.2 grams (g)/day, compared with the average WHO child, which gained 8.9 g/day.

Similarly, Gordon et al (2003) examined body composition by anthropometry and dual energy x-ray absorptiometry (DEXA) in 41, 3- to 7-year old Pacific children living in NZ. Children were tall and heavy for their age, with height-for-age and BMI-for-age z-scores of 1.33 (0.60, 2.15) and 1.20 (0.74, 4.43) respectively. Their median percentage body fat (%BF) was 21.8%, and over 60% of children had trunk levels of fat over one standard deviation (SD) of reported age- and sex- specific z-scores for NZ children.

To comply with international standards, NZ health surveys have relied on international BMI cut-off points to classify children as overweight or obese (Ministry of Health, 2003; Ministry of Health, 2008b). There is evidence, however, that current BMI cut-off points may however overestimate obesity in Pacific and Maori populations, who have been demonstrated to have lower levels of body fat at a given BMI than European populations (Swinburn et al., 1996; Rush et al., 1997; Swinburn et al., 1999). For example, Rush et al. (2003) reported Pacific and Maori girls aged 5 to 14 years had on average 3.7% less body fat than European for a fixed BMI. Nonetheless, when higher overweight and obesity cut-off points are used to correct for the difference in the ratio of lean-to-fat mass, Pacific and Maori populations are still twice as likely to be obese as NZ European and Other (Ministry of Health, 1999).

Conversely, current BMI cut-off points may underestimate the prevalence of overweight and obesity in Asian populations, who have been demonstrated to have higher levels of body fat at a given BMI than European (Deurenberg et al., 1998; Deurenberg et al., 2002; World Health Organisation Expert Consultation, 2004). Asian ethnic groups also have a tendency for central fat accumulation (Park et al., 2001), which combined with a low lean-to-fat ratio, may place this group at risk of obesity related diseases at relatively low BMI values.

Furthermore, body composition varies among Asian ethnic groups (Deurenberg et al., 2002). Indian Asians, for example, have been found to have a greater central fat mass than Malay and Chinese Asians (Hughes et al., 1997).

As with large body size in Pacific populations, the trajectory of small body size with high body fat observed in Indian populations – known as the ‘thin-fat’ phenotype - appears to be established before birth. Yajnik et al. (2003) compared body size and fat in Indian babies born in rural India and white babies born in the UK. Although Indian babies were lighter and smaller in all measurements compared with white babies (with an abdominal circumference SD score -2.38 and mid-arm circumference SD score -1.82), fat mass was generally spared, with an SD score of only -0.53. The authors concluded that in underweight Indian babies, muscle and abdominal viscera are ‘sacrificed’ while fat deposition continues.

The ‘thin-fat’ phenotype may predispose Indian children to higher rates of T2DM and CVD later in life (Yajnik, 2004). When the prevalence of T2DM in NZ was examined among Asian ethnic groups, Indian adults were found to have three times the prevalence of T2DM of the general population (Ministry of Health, 2006), similar to the prevalence in observed in Pacific adults in NZ (Ministry of Health, 2008b).

In summary, there are clear ethnic differences in body composition and the prevalence of obesity and obesity related diseases. Ethnic disparity needs to be addressed and will require an understanding of risk factors related to the accumulation of excess body fat within each ethnic group, such as exposure to adverse intrauterine environment and obesogenic food and activity patterns during childhood.

1.2.2 Food and activity patterns and childhood obesity

A healthy diet during childhood is important for normal growth and development. Undernutrition and micronutrient deficiencies can lead to poor growth (Rivera et al., 2003) and cognitive functioning (Black, 2003), while overnutrition promotes fat accumulation and obesity. With children’s intakes of macronutrients (Singer et al., 1995; Wang et al., 2002), fruits and vegetables (Resnicow et al., 1998; Wang et al., 2002), meats and oils (Wang et al., 2002), overall food preferences (Skinner et al., 2002) and physical activity (Pate et al., 1996) shown to track for periods of 19 months to over 6 years, establishing healthy food and activity patterns in early childhood could have long-ranging effects.

There is limited research examining food and activity patterns in preschool children in NZ. Four main studies will be reviewed in this section (and referred to throughout this thesis): the Auckland Birth Cohort (ABC) study by Theodore et al. (2006), which examined dietary patterns in a sample of 550, 3.5-year old NZ European children; the NZ Children’s Nutrition Survey (CNS) pilot study which examined food and activity patterns in 91, 1- to 4-year old NZ European, Maori and Pacific children (Ministry of Health, 2001); the Pacific Island Families (PIF) study, which examined food patterns in 739, 4-year old Pacific children (Rush et al., 2008a); and finally, a study by Soh et al. (2000), which examined eating patterns in 17 Asian (predominantly Chinese) preschool children. Results of the 2002 NZ National Children's Nutrition Survey (CNS), which examined the diets of 3275, 5- to 14-year old NZ European and Other, Pacific and Maori children (Ministry of Health, 2003), will also be discussed. No studies were found which examined food and activity patterns in NZ Indian children exclusively.

1.2.2.1 Patterns of food and food group consumption

The Ministry of Health (MoH) food and nutrition guidelines for children aged 2 to 12 years (Ministry of Health, 1996) are referred to in this section and a summary of these guidelines is presented in Appendix 1.

Fruit and vegetables

Children aged 2 years and over in NZ are recommended to consume at least two servings of fruit and two servings of vegetables per day (Ministry of Health, 1996). Fruit and vegetables contain carbohydrates, vitamins, minerals and dietary fibre. Low consumption in early childhood has been associated with inadequate intakes of vitamin A, vitamin C and dietary fibre, and high intakes of saturated fat (Dennison et al., 1998). According to the 2002 CNS (Ministry of Health, 2003), fruit and vegetables are among the main sources of vitamin A (as β-carotene), vitamin C and vitamin E in NZ children's diets.

The CNS pilot study found 74% of children consumed the recommended two servings of fruit, and 47% consumed the recommended two servings of vegetables per day (Ministry of Health, 2001). Similarly, in the ABC study, 73% of children consumed the recommended two servings of fruit a day, and 68% of children consumed fruit two times per day (Theodore et al., 2006). However, in the ABC study, although 77% of children reported consuming vegetables twice a day, only 46% consumed the recommended two servings. The authors suggested the discrepancy between the high percentage of children consuming vegetables two *times* a day and the low percentage consuming two *servings* a day may indicate children are not consuming whole servings of vegetables. In the study of NZ Asian preschool children, Soh et al. (2000) reported that less than 40% of children met the recommended two servings each of fruit and vegetables per day.

Fruit and vegetable consumption appears to decline with age. In the 2002 CNS less than half of children consumed fruit at least twice a day, with younger children consuming more fruit than older children (Ministry of Health, 2003). Although almost 60% percent of children consumed vegetables three times or more per day (the recommended number of servings for older children), it is worth noting two of the vegetables most likely to be eaten weekly were 'other potatoes' (boiled, mashed, baked and roasted) and 'fried potatoes' (hot potato chips, kumara chips, fries, hash browns or wedges).

There is a plausible mechanism by which fruit and vegetable consumption could protect against excess body fat. Due to their high water content, fruit and vegetables have a low energy density and may displace more energy-dense foods in the diet, thus reducing overall energy intake. Nonetheless, in a US study of 1,379 children aged 2 to 5 years (Newby et al., 2003) fruit, vegetable, and fibre intakes were not significantly associated with annual weight change; and in a recent review of 13 studies examining fruit and vegetable intake and childhood obesity, Newby (2009), concluded there was no evidence to suggest increased fruit and vegetable intake is protective against childhood obesity. The author did state however that most of the studies reviewed were poorly designed, and because most children do not meet the recommended amount of fruit and vegetables, increased consumption should be encouraged.

Milk and dairy products

Milk and dairy products are important sources of dietary calcium and protein, and children are recommended to consume two to three servings of milk or dairy products per day (Ministry of Health, 1996). For children aged 1 to 2 years, up to two servings (500 millilitres (mls)) of standard full-fat cows' milk per day is recommended, with no sugar or flavorings added (Ministry of Health, 2008a). After 2 years of age, reduced-fat and low-fat milk and dairy products can be introduced to children's diets.

Milk and dairy products are important sources of calcium in the NZ diet. The greatest contributors to dietary calcium among 5 to 14 year old children in the 2002 CNS were milk bread, cheese, dairy products and beverages. Milk and dairy products were also the main contributors of vitamin A (as retinol) in children's diets.

Among 1 to 4 year olds in the CNS pilot study, 84% of children consumed the recommended two servings of milk or dairy products per day. Standard full-fat milk was drunk by 70 to 80% of children, with reduced-fat milk the next most popular. Similar results were obtained in the ABC study, with 86% of preschoolers meeting the recommended two or more servings of milk or dairy products per day (Theodore et al., 2006). Though in total 85% reported consuming milk one or more times per day, only 9% consumed reduced-fat or low-fat milk this often. The preference for full-fat milk over reduced-fat versions was also observed among older children in the 2002 CNS (Ministry of Health, 2003).

In addition to the importance of calcium for bone health in children, evidence from epidemiological studies suggests that a higher dietary calcium intake is associated with reduced body fat (Zemel, 2002; Heaney, 2003). In a study of 53 children, Carruth and Skinner (2001; 2003) reported that mean longitudinal calcium intake and total servings of dairy products per day at ages 2 to 5 years were significantly associated with lower body fat at 6 and 8 years. Barbra et al. (2005) found a significant inverse association between frequency of milk consumption in 7.5 year old children and BMI z-score. Finally, a longitudinal study in 178, 3 to 5 year old children (DeJongh et al., 2006) examined the effect of 1 year of calcium supplementation on change in fat mass. Among children in the lowest tertile of dietary calcium intake (<821 milligrams (mg)/day), fat mass gain was lower in the group supplemented with calcium (0.3 ± 0.5 kilograms (kg)) than in the group receiving a placebo (0.8 ± 1.1kg).

Calcium has been shown to modulate lipolytic activity in human adipocytes (Zemel et al., 2000; Xue et al., 2001), providing a mechanism by which calcium could reduce body fat. Trials of calcium supplementation in adults however have shown little or no effect on fat mass (FM) (Davies et al., 2000; Barr, 2003), suggesting the protective effect of milk and dairy products against excess body fat could be due at least in part to other bioactive components (Barba et al., 2005).

In addition to plain milk, sweetened milk appears to be a popular beverage for NZ children. In the ABC study, milkshakes and sweetened milk were consumed by 49% of children at least once a week (Theodore et al., 2006). Among 4 year old Pacific children in the PIF study, food drinks (such as Milo and Nesquik) were in the top 40 most frequently eaten foods, consumed on average 0.58 times per day (Rush et al., 2008a). In the 2002 CNS, food drinks were consumed by more than half of children weekly, while 22% reported consuming flavoured milk and 13% consumed a milkshakes this often (Ministry of Health, 2003). A greater proportion of Pacific children consumed flavoured milk and milkshakes weekly than NZ European and Other and Maori children.

Limited research has examined the association between sweetened milk consumption and obesity. A recent study involving 7,557 children and adolescents aged 2 to 18 years (Murphy et al., 2008) found that children aged 2 to 5 years who consumed exclusively plain milk had significantly lower added sugar intakes compared to children who consumed flavoured milk or did not consume milk at all. BMI status in 2 to 5 year old children however was not significantly different between the three groups. Nutrient intakes were higher in children who consumed plain milk and flavored milk than those who did not consume milk.

Meat and other protein

Protein is needed for growth and repair, and preschool children in NZ are recommended to consume at least one serving of lean meat, chicken, seafood, eggs, dried peas, lentils or beans every day (Ministry of Health, 1996). In addition to supplying protein, foods such as lean meat, chicken and seafood are good sources of iron (Ministry of Health, 1996) and vitamin B_{12} (Antony, 2003).

Preschoolers in NZ are at risk of iron deficiency (Adams et al., 1997; Soh et al., 2002), and the prevalence of iron deficiency varies among ethnic groups. In a sample of 6 to 23 month old NZ European, Maori, Pacific and Other children, iron deficiency was present in 27% of Other, 20% of Maori, 17% of Pacific and 7% of European children, and was associated with a BMI of >18.5kg/m² and with receiving no infant or follow on formula (Grant et al., 2007b). In a study of NZ European, Maori and Pacific children aged 6 to 23 months, the main sources of iron for children aged 12 to 23 months were cereals, fruit and vegetables (Wall et al., 2009).

Overseas studies have demonstrated the importance of meat as a source of iron for young children. In Australia, consuming red meat less than four times a week was associated with iron depletion in a study of 9 to 62 month old children (Karr et al., 1996) and in a case-control study of iron depleted and iron replete children aged 12 to 36 months, haem iron intake was significantly lower in iron depleted children (Mira et al., 1996). In a UK study of 1000 children aged 1.5 to 4.5 years, iron status was directly associated meat and fruit intake, and inversely associated with cow's milk intake (Thane et al., 2000). However, in the NZ study mentioned above by Wall et al. (2009) , Pacific children were the greatest consumers of meat and haem iron, suggesting factors other than low meat consumption contribute to the high prevalence of iron deficiency in this ethnic group.

A high percentage of children in NZ appear to meet the recommended servings of meat and other protein. Of 1 to 4 year old children in the CNS pilot study, 84% consumed one or more servings of protein products (lean meat, chicken, seafood, eggs, dried peas, lentils and beans) every day (Ministry of Health, 2001). Similarly, in the ABC study 88% of preschoolers consumed at least one serving of meat, chicken, fish or eggs daily (Theodore et al., 2006). Chicken was the most popular protein food in the ABC study, and among older children in the 2002 CNS (Ministry of Health, 2003; Theodore et al., 2006). In the study of preschool Asian children, around 75% were found to meet the recommended one serving of meat and other protein each day (Soh et al., 2000).

The inclusion of more animal protein in the diet at the expense of plant food could have a role in promoting obesity. A longitudinal German study found that animal protein intake at 12 months and 5 to 6 years was positively associated with body fat percentage (%BF) at 7 years (Gunther et al., 2007) and in Japanese school children, the increased intake of animal protein and fat correlates with the increased incidence of T2DM (Kitagawa et al., 1998).

At the other end of the spectrum, very low meat consumption could be involved in the programming of obesity. As reviewed later in this chapter, vitamin B_{12} is an important methyl donor involved in normal cell growth and division, and may play a role in the epigenetic programming of obesity (Waterland et al., 2003). Studies in India have linked maternal B_{12} deficiency and high erythrocyte folate concentrations with decreased size at birth and increased adiposity and insulin resistance in offspring at 6 years of age (Yajnik et al., 2005; Yajnik et al., 2008). Non-meat eating dietary practices are common among the Indian population for religious and cultural reasons and may place this group at risk of vitamin B_{12} deficiency (Antony, 2001; Antony, 2003). A recent study of six meat eating and six non-meat eating migrant Indian girls aged 9 to 11 years in NZ found that serum B_{12} was lower in the non-meat eating girls (Rush et al., 2009). To the authors knowledge, no studies in NZ have yet examined meat consumption or B_{12} deficiency in young Indian children.

Breads and cereals

Breads and cereals are an important source of energy and folate in children's diets (Ministry of Health, 2003) and young children are recommended to consume at least four servings of breads and cereals (including rice, pasta and noodles), every day (Ministry of Health, 1996).

In the CNS pilot study, 'most' children consumed an adequate quantity of breads and cereals (Ministry of Health, 2001), with around 60% of children consuming three or more servings of bread per day, and 60% consuming three or more servings of cereals (noodles, pasta and rice) per week. Seventy-two percent of children reported consuming white bread, with wholemeal the next most popular. Conversely, in the ABC study (Theodore et al., 2006), only 7% of children consumed the recommended four or more servings of breads and cereals per day. Bread and breakfast cereal were the most popular foods in the breads and cereals category, consumed daily by 79% and 44% of children respectively. Of breads, white bread was again the most popular with 78% of children reporting consumption at least once a week. The next most popular was mixed grain, consumed by 60% of children this often. Among Asian preschool children in NZ, rice was the most commonly eaten food from the breads and cereals group (Soh et al., 2000).

White bread was also the most popular bread among older children in the 2002 CNS, followed by whole meal and mixed grain (Ministry of Health, 2003). The type of bread consumed varied among ethnic groups: Pacific children were the most likely to usually consume white bread and the least likely to usually consume mixed grain bread, while NZ European and Other children were the most likely to consume mixed grain bread and the least likely to consume white bread.

Breads and cereals are a major source of dietary fibre for NZ children (Ministry of Health, 2003). Consumption of fibre in early childhood may be important for preventing constipation, a common problem in preschoolers (Williams, 1995; Corkins, 2005). There has been some concern in the past that high fibre diets in early childhood could inhibit mineral absorption and may result in children being unable to meet energy requirements for growth. There is, however, little evidence to support these concerns, especially in developed countries. A recent study from Finland, which longitudinally examined fibre intake in 543 children aged 8 months to 9 years (Ruottinen et al., 2010), showed that fibre intake was positively associated with energy intake and inversely associated with fat intake and serum cholesterol concentrations. Furthermore, fibre intake had no affect on the height or weight of children and children who consumed more dietary fibre received more vitamins and minerals than children consuming less.

Breads and cereals also appear to be protective against childhood obesity. In an Australian study of 340, 8 year old children, a food pattern with breads and cereals as the major component was inversely associated with BMI (Burke et al., 2005). Breakfast cereal, a popular food for young children in NZ, is associated with improved diet quality (Gibson et al., 1995; Albertson et al., 2003; Barton et al., 2005) a reduced risk of childhood obesity (Ortega et al., 1998; Albertson et al., 2003; Kafatos et al., 2005).

Wholemeal and wholegrain breads and cereals may be particularly protective against obesity (Koh-Banerjee et al., 2003). High glycaemic index (GI) refined breads and cereals, such as white bread and white rice, may promote weight gain by increasing appetite (Ludwig et al., 1999), or through an effect on insulin levels, as hyperinsulinaemia has been shown to direct glucose away from oxidation in muscle and towards storage in adipose tissue (Cusin et al., 1992). Wholegrain consumption by young children is low, and in the US ranges from 0.8 servings per day for preschool children to 1.0 serving for school aged children (Harnack et al., 2003). As reviewed earlier, refined carbohydrates such as white bread and white rice, are more popular than wholemeal and wholegrain versions among children in NZ.

Treat foods

In this thesis, treat foods refers to biscuits, cakes, crisps, muesli bars, lollies, and chocolate bars (but not sweet drinks or takeaways, which are examined separately). As these foods are generally energy-dense and nutrient-poor, children are recommended to consume treat foods only occasionally (Ministry of Health, 1996).

Despite the MoH recommendation, a high proportion of young NZ children appear to consume treat foods on a regular basis. In the ABC study (Theodore et al., 2006), total treat foods (cakes, biscuits, candy bars, chips and muesli bars) were consumed daily by 85% of children, and 12% consumed these foods three or more times per day. Biscuits and cakes were the most popular treat foods, consumed daily by 56% of children. In the PIF study, potato crisps, corn snacks or other chips; biscuits; chocolate coated or cream filled biscuits; and other convenience meals or snacks items were in the top 40 most frequently eaten foods, consumed on average between 0.32 and 0.43 times per day (Rush et al., 2008a).

Among 5 to 14 year children in the 2002 CNS, treat foods consumed by more than half of children weekly included biscuits, crackers or crisp breads, bars, and chocolate-coated or cream filled biscuits (Ministry of Health, 2003). The category 'sugar and sweets' contributed 21% of total sucrose (the main sugar) in children's diets and biscuits and crisps alone contributed 10% of the total fat.

High consumption of treat foods may lead to reduced consumption of other nutrient-dense foods, and poorer diet quality. A study of over 10,000, 1 year old children (Brekke et al., 2007) found that one-quarter of children consumed sweets and pastries more than once or twice a week, and that these children had higher intakes of French fries, potato crisps and cream, and lower intakes of fruits and vegetables. Spurrier et al. (2008) reported that preschool children who had restricted access to high-fat and high-sugar foods had higher fruit and vegetable intakes and lower intakes of non-core foods.

There is limited research examining the association between treat food consumption and obesity in early childhood. The Bogalusa Heart Study, in which dietary patterns were examined in 10 year old children, found that the consumption of sweets (desserts, candy and sweetened beverages) and overall consumption of low-quality foods (salty snacks, candy, desserts, fats and sweetened beverages) was associated with overweight status (Nicklas et al., 2003a). The total gram amount of food consumed, in particular that from snack food, was also associated with overweight. Furthermore, in a prospective study of low income preschoolers (Newby et al., 2003), each additional daily serve of 'fat' food (including ice-cream, crisps, biscuits, cakes and chocolate) was associated with a 0.05kg greater weight change per year.

Conversely, an Australian study of children and adults aged 2 to 80+ years found that while non-core foods were consumed in excess by children; non-core food consumption was not associated with overweight or obese status (Bell et al., 2005). Two prospective studies of 15,000, 9 to 14 year old boys and girls (Field et al., 2004) and 196, 8 to 12 year old girls (Phillips et al., 2004) similarly found no association between snack food intake and change in BMI z-score.

Sweet drinks

In this thesis 'sweet drinks' refers to sugar sweetened drinks, such as cordial, fruit drinks and soft drinks, as well as 100% fruit juice. It is recommended that children in NZ drink water or plain milk rather than sweet drinks from a young age, so they do not develop a taste for sweetened beverages (Ministry of Health, 1996). Although 100% fruit juice is high in vitamin C and does not have any added sugar, it contains similar amounts of sugar to sugar sweetened beverages (Table 1.1), and children who consume large quantities of these drinks may displace other nutrient dense foods in their diets (Ministry of Health, 1996).

Table 1.1 Sugar content of popular drinks in NZ

Drink	Type	Sugar in one serve (250ml)*
Plain milk	Standard full-fat milk	11 grams
Sweetened milk	Milo (15g) with standard milk	18 grams
Fruit juice	Just juice, orange and apple	26 grams
Sugar sweetened drinks	Lemon barley cordial with water	22 grams
	Lemonade	27 grams

g = grams**; ***From the Concise New Zealand Food Composition Tables (NZ Institute for Crop and Food Research Limited, 2006)

The consumption of sweet drinks appears to be high among children in NZ. In the ABC study 30% and 35% of children consumed juice and cordial, respectively, at least once a day and 24% consumed soft drinks at least three times a week (Theodore et al., 2006). Powdered fruit drink and juice were in the top 40 most frequently eaten foods by children in the PIF study, consumed on average 0.51 and 0.46 times per day respectively. (Rush et al., 2008a),

Among older children in the 2002 CNS (Ministry of Health, 2003), soft drinks, Coca-Cola and Mountain Dew were consumed weekly by 45%, 43% and 9% of children respectively. Powdered fruit drink was consumed by 54% of children weekly, and fruit drink from concentrate or cordial was consumed by 32% of children weekly. Higher proportions of Pacific and Maori children consumed powdered fruit drink, Coca-Cola and other cola drinks, and Mountain Dew weekly than NZ European and Other children.

Beverages were among the main contributors to total dietary sugars in the 2002 CNS (Ministry of Health, 2003). In a study of 60, 2 to 5 year old Pacific children in NZ (Grant et al., 2004), sugar intakes were high and contributed to just under half the energy intake from carbohydrates, with sucrose contributing just under half the energy intake from sugars. Children classified as obese (BMI >95th percentile) had diets that were higher in the percentage of energy contributed by sucrose than non-obese children (15.1% versus 11.6% respectively, $p = 0.13$), especially sucrose from beverages.

The consumption of sugar sweetened drinks and fruit juice has been associated with an increased risk of childhood obesity in most (Ludwig et al., 2001; Giammattei et al., 2003; Welsh et al., 2005; Faith et al., 2006; Dubois et al., 2007; Fiorito et al., 2009) but not all studies (O'Connor et al., 2006). In a US study of 225 children aged 2 and 5 years (Dennison et al., 1997), those consuming 355 ml or more of fruit juice per day were shorter than children consuming less juice (86.5 versus 89.3 centimeters (cm) for the 2 year old children, and 106.5 versus 111.2 cm for the 5 year old children) and more overweight (BMI = 17.2kg/m^2 versus 16.3kg/m^2).

Sugar sweetened drink consumption may be particularly effective in perpetuating or maintaining overweight status in children who are at risk of overweight or already overweight. A retrospective study of 10,904 US preschool children aged 2 and 3 years examined the association between sugar sweetened drink consumption and overweight at follow up (Welsh et al., 2005). Among children who were normal weight or underweight at baseline, the relationship between sugar-sweetened drink consumption and obesity was positive but not statistically significant. Among children who were at risk of overweight at baseline (BMI 85th to <95th percentile), those consuming 1 to < 2 drinks per day, 2 to < 3 drinks per day and 3 drinks per day were 2.0, 2.0 and 1.8 times, respectively, as likely to become overweight as children drinking less than one sugar sweetened drink per day. Among children who were overweight at baseline (BMI >95th percentile), those consuming 1 to < 2 drinks per day, 2 to < 3 drinks per day and 3 drinks per day were 2.1, 2.2 and 1.8 times more likely to remain overweight as children consuming less than one sugar sweetened drink per day.

The regular consumption of sugar-sweetened drinks and fruit juice could promote weight gain by leading to increased energy intake. Sweet drinks have high GIs, and as mentioned above, high GI foods may lead to over consumption through appetite dysregulation (Ludwig et al., 1999), and increased storage of glucose as fat (Cusin et al., 1992). Studies in adults have shown carbohydrates consumed in liquid form elicit poor dietary compensation (Mattes, 1996), leading to overall increased energy intake.

Takeaways

In this thesis, takeaways refers to foods bought from fast food outlets such as McDonalds, Kentucky Fried Chicken and Burger King, as well as fish and chips, pizza, Chinese takeaway food and Indian takeaway food. Because these foods tend to be energy-dense, high in salt, and nutrient-poor, children in NZ are recommended to consume these foods occasionally only (Ministry of Health, 1996). Unsurprisingly, the authors of a large US study of 6,212 children and adolescents aged 4 to 19 years (Bowman et al., 2004) reported that takeaway consumption had an adverse effect on children's energy intake and diet quality. When compared with children who did not consume takeaways on either of two diet survey days, children who consumed takeaways on one survey day consumed more total energy, more energy per gram of food, more total fat, more total carbohydrate, more added sugars, more sugar-sweetened beverages, less fibre, less milk and fewer fruit and non-starchy vegetables. Similar results were obtained in a study of 17,370 adults and children (Paeratakul et al., 2003), where individuals who reported consuming takeaways consumed more energy, fat, saturated fat, sodium and soft drinks, and less milk, fruits and vegetables than individuals who did not report consuming takeaways.

Little research has examined takeaway consumption among preschool children in NZ. Almost half of the children in the CNS pilot study consumed one to two servings of takeaway foods per week, and 13% consumed more than two servings of takeaways per week (Ministry of Health, 2001). In the recent 2006/2007 NZ Health Survey, 70% of children aged 2 to 14 years had consumed takeaways at least once during the past 7 days, and 7% had consumed takeaways three or more times during this period. Pacific children were twice as likely as children in the general population to have consumed takeaways at least three or more times in the past 7 days, and European and Other children were less likely to have consumed takeaways three or more times during this period (Ministry of Health, 2008b).

Studies linking takeaway consumption with obesity in early childhood are lacking, and in older children the evidence is limited. In a study of 8 to 12 year old girls (Thompson et al., 2004), those who consumed two or more servings of takeaway style ('quick-service') foods at baseline had a greater change in BMI z-score 3 years later compared with girls who consumed one or fewer servings of takeaways per week . Conversely, in a study of 4,746 adolescent students no association between fast food restaurant use and overweight status was observed, despite the frequency of fast food restaurant use being positively associated with total energy and energy from fat; and negatively associated with servings of fruit, vegetables and milk (French et al., 2001). In a recent systematic review, Rosenheck (2008) concludes that there is sufficient evidence to suggest takeaway (i.e. fast food) consumption is associated with weight gain, however further research is needed to examine the association among children and adolescents.

1.2.2.2 Patterns of daily food consumption

Number of eating occasions

Regular meals and snacks are important for young children, who may not be able to obtain required energy and nutrients from three main meals alone (Ministry of Health, 1997). Research has demonstrated that children who have less than four eating occasions per day consume less energy and nutrients than their peers, while children who eat more than six times a day consume more energy and nutrients (Network of the Federal/Provincial/Territorial Group on Nutrition and National Institute of Nutrition (A joint project), 1989). In the CNS pilot study, the majority of children had two to three eating occasions before noon, two to three after noon and before 5pm, and one to two after 5pm and before rising, thus eating on average five to eight times per day (Ministry of Health, 2001). Similarly, in the US Feeding Infants and Toddlers (FIT) study, which examined eating patterns in over 3,000 infants and toddlers aged 4 to 24 months, children had on average seven eating occasions per day (Skinner et al., 2004).

A cross-sectional study of German children aged 5 and 6 years found increased meal frequency was associated with a reduced risk of obesity (Toschke et al., 2005b). Among children who had three or fewer eating occasions per day 4.2% (confidence interval (CI) 2.8-6.1) were obese, compared with 2.8% (CI 2.1-3.7) of those who had four eating occasions and 1.7% (1.2-2.4) of those who had six or more eating occasions. The adjusted odds ratios (OR) associated with obesity were 0.73 (CI 0.44-1.21) for four eating occasions and 0.29 (CI 0.29-0.89) for five or more eating occasions.

Other studies have had conflicting results: in a US study of children and adolescents aged 3 to 5 years, 6 to 11 years and 12 to 19 years, an inverse association between meal frequency and BMI percentile was only observed among boys aged 12 to19 (Huang et al., 2004) and in another US study an association between meal frequency and obesity was only observed in African American 10 year old females, with no association observed in African American males, or European males and females (Nicklas et al., 2003b).

An increased number of meals or eating occasions could protect against obesity by improving control over food intake. For example, Speechly et al. (1999) demonstrated that when obese adult men were given an isoenergetic preload divided into a multi-meal, they consumed 27% less at a subsequent *ad libitum* meal than those who consumed the preload as a single meal. It is not yet known whether increased meal frequency has the same effect in young children.

Foods consumed at meals and snacks

There is limited research examining the type of foods preschool children consume at meals. In the study of Asian preschool children in NZ, Soh et al (2000) reported foods children commonly ate for breakfast were bread, noodles, milk and eggs. Cold breakfast cereal was not commonly consumed. For lunch and dinner rice, vegetables, meat, fruit and eggs were popular foods. Snacks included milk, yoghurt, biscuits, sweets, fruit and chips. Children who attended preschool facilities were introduced to Western foods such as sausages, cheese on toast or crackers, cold meats and cordial, which were not consumed at home. After an extensive literature search, no other studies which have examined meal patterns (i.e. foods consumed at meals) of NZ toddler or preschool children were found.

In the US FIT study the most popular breakfast foods for 19 to 24 month olds were whole milk, eggs, unsweetened breakfast cereal, butter and bread (Skinner et al., 2004). Popular lunch foods included chicken, bread, whole milk, sandwiches, cheese and hotdogs or sausages, and for dinner children consumed chicken, pasta or rice, whole milk, bread, cheese and butter. In between meals children snacked on foods such as fruit drinks, candy, chips, cookies, milk and crackers. Around half the children did not consume fruit at breakfast and lunch, and 60% did not consume fruit at dinner. More than half of children did not consume vegetables at lunch, and around one-third had no vegetables for dinner. Fruit and vegetables were rarely consumed as snack foods by 19 to 24 month old children in this study.

1.2.2.3 Patterns of daily activity

Sleep

In the NZ CNS pilot study (Ministry of Health, 2001), 1 to 5 year old children slept between 10 and 11 hours per night, and four out of five children had a daytime sleep as well. Overseas studies have identified ethnic differences in sleep patterns. In a cross-sectional study of primary school children in China and the US, Liu et al. (2005) reported children in China went to bed half an hour later and woke up half an hour earlier than their US counterparts, resulting in one less hour of sleep a night. Within the US, a study of 2 to 8 year black and white children found that black children were significantly more likely to nap than white children and slept significantly less at night during weekdays (Crosby et al., 2005); and a study of 8 to 11 year old children (containing 35% minority ethnic groups) found that minority children slept significantly less hours per night than non-minority children at all ages (Spilsbury et al., 2004).

Population and laboratory studies have provided increasing evidence of an association between short sleep duration and obesity, across all age groups and a number of ethnicities (Kagamimori et al., 1999; Sekine et al., 2002b; von Kries et al., 2002; Hui et al., 2003; Agras et al., 2004; Cournot et al., 2004; Gangwisch et al., 2005; Reilly et al., 2005b; Chaput et al., 2006; Snell et al., 2007b; Duncan et al., 2008; Touchette et al., 2008). This association appears to be more robust in children. A recent meta-analysis examined the relationship between short sleep duration and obesity in over 30,000 children and 600,000 adults (Cappuccio et al., 2008). In children the pooled OR for short sleep duration and obesity was 1.89 (1.46 to 2.43) compared with 1.55 (1.43 to 1.68) in adults.

There appears to be a dose-response relationship between sleeping hours and obesity. A longitudinal study of over 10,000 children found that at 3 years of age the frequency of sleeping less than 10 hours per night was greater in obese children than in non-obese children (Kagamimori et al., 1999). By the age of 6 to7 years a significant dose-response relationship was observed (Sekine et al., 2002b). Compared to children sleeping more than 10 hours per night, the adjusted OR for obesity was 1.49 (1.08 to 2.14) for those sleeping 9 to 10 hours, 1.89 (1.34 to 2.73) for those sleeping 8 to 9 hours and 2.87 (1.61 to 5.05) for those sleeping less than 8 hours. Similarly, in a multiethnic sample of New Zealand children aged 5 to 11 years the adjusted OR for obesity was 3.92 (1.07 to 14.4) for those sleeping 11 to 11.9 hours, 4.23 (1.13 to 15.8) for those sleeping 10 to 10.9 hours and 7.03 (1.63 to 30.4) for those sleeping less than 10 hours, compared with children sleeping 12 or more hours per night.

Though the mechanism by which short sleep duration is associated with obesity is not fully understood, there is evidence to suggest the activation of hormonal responses may play a role (Spiegel et al., 2004; Taheri et al., 2004). Appetite and energy intake are regulated in part by the anorexigenic effects of leptin and the orexigenic effects of ghrelin. Research has demonstrated that leptin and ghrelin levels may be dependent on sleep duration. Spiegel et al. (2004) examined the effect of 2 days of sleep restriction on appetite regulation in young men. Sleep restriction was associated with an 18% decrease in leptin and a 28% increase in ghrelin. Participants also reported a 24% increase in hunger, and a 23% increase in appetite for all food groups combined. The greatest increase in appetite was observed for high carbohydrate, calorie dense foods.

Interestingly, there is evidence to suggest that short sleep duration in early childhood may predict obesity in later childhood. A longitudinal study of 900 children, where sleep duration was recorded at 6, 12 and 24 months, found that after controlling for confounders, sleep duration of less than 12 hours per day during infancy was associated with an increased BMI z-score at 3 years of age (Taveras et al., 2008). Similarly, analysis of the Avon longitudinal study in the UK revealed that short sleep duration at age 3 was associated with obesity at age 7 (Reilly et al., 2005b). As sleep is thought to be important for brain development and plasticity in children, these results could indicate short sleep duration at a young age alters the hypothalamic mechanisms regulating appetite and energy balance (Taheri, 2006).

In addition to the duration of sleep, there is evidence to suggest timing of sleep may predict obesity. Snell et al (2007b) examined sleep in relation to BMI and overweight status in children and adolescents aged 3 to 12 years at baseline. Late bedtime and early wake-up time at the first assessment were associated with a higher BMI 5 years later. Similarly, a dose-response relationship was observed between late bedtime and obesity in a longitudinal study of 10,000 children at ages 6 to 7 years, though no association was observed for wake-up time (Sekine et al., 2002b).

Physical activity

As with eating patterns, physical activity levels in early childhood have been shown to track into later childhood (Pate et al., 1996). Although there is no explicit amount of physical activity recommended for 2 year old children in NZ, older (5 to 18 year old) children and adolescents are recommended to engage in 60 minutes of moderate to vigorous physical activity every day (Sport and Recreation New Zealand, 2007). Some researchers suggest that despite the widespread belief that young children are very active, increased TV watching, time spent at daycare and greater parental constraints on play due to safety concerns have led to declines in young children's physical activity levels (Davies et al., 1995; Salbe et al., 1997; Boreham et al., 2001). In a systematic recent review of 39 studies involving over 10,000 children aged 2 to 6 years, Tucker (2008) reported that nearly half of the preschool children studied did not engage in sufficient physical activity (60 minutes a day of moderate to vigorous physical activity).

Physical activity is protective against obesity, and although most studies have been conducted in older children and adolescents, there is evidence of an inverse relationship from early childhood. In the longitudinal Framingham Children's Study (Moore et al., 1995), physical activity was objectively measured using an electronic motion sensor, and children were followed from the age of 3 to 5 years until the start of first grade. On average, inactive girls gained 1.75mm in their triceps skinfold from baseline to first grade, while active girls gained only 1.0mm. Inactive boys gained on average 0.25mm in their triceps, while active boys lost an average of 0.75mm. Controlling for other variables, inactive preschoolers were 3.8 (CI 1.4 to 10.6) times more likely to have an increasing triceps slope during follow up (as opposed to a stable or decreasing slope) than active preschoolers. More recently, studies which have used accelerometers to objectively measure activity in preschool children have also demonstrated an inverse relationship between physical activity and risk of overweight (Janz et al., 2002; Trost et al., 2003)

Furthermore, studies which have relied on parental estimates of children's activity levels have found an inverse relationship. Goran et al (1997) reported physical activity level, as determined by mothers' responses to a questionnaire, was inversely associated with fat mass in young children, while Klesges et al (1995) reported aerobic activity level, as estimated by both parents, was associated with decreased subsequent changes in a young child's BMI.

There are several mechanisms by which physical activity is hypothesised to protect against excess weight gain, though these are poorly studied in children. Physical activity may protect against obesity by increasing energy expenditure and resting metabolic rate (Poehlman, 1989), by beneficially affecting substrate metabolism and increasing the utilisation of fat, relative to carbohydrate, for fuel (Almeras et al., 1995) and by improving food intake regulation (Goran et al., 1999).

Television watching

There is no recommended limit on time spent watching television (TV) for 2 year old children in NZ, however the American Academy of Pediatrics recommends children aged >2 years watch less than 2 hours of TV per day (American Academy of Pediatrics Committee on Public Education, 2001). In the CNS pilot study, children spent around 5.8 to 7.0 hours per week watching TV. Time spent watching TV appeared to increase with age, with boys from 3 years onwards more likely to watch TV or spend time on a computer In the US, Certain et al. (2002a), reported that 48% 12 to 23 month olds and 41% of 24 to 35 month olds watched more than 2 hours of TV per day. Furthermore, there may be ethnic differences in the amount of TV young children watch. In a study of 1 to 5 year old US children (Dennison et al., 2002), white children watched on average 12.7 hours of TV per week while Hispanic children watched 15.0 hours and black children watched 17.5 hours.

A positive relationship between TV watching and obesity appears to be present from early childhood. After analysing weight, adiposity, and TV viewing in 1809, 2 to 5 year old children using data from the National Health and Nutrition Examination Survey, Mendoza et al. (2007) reported that watching greater than 2 hours of TV per day was associated with higher adiposity (determined by skin fold thickness) and with being overweight or at risk of overweight. In the Framingham Children's Study, children's TV watching behavior was an independent predictor of change in BMI, triceps skin-folds and sum of five skin-folds between the ages of 4 and 11 years (Proctor et al., 2003). By the age of 11, children who watched 3 hours or more of television per day had a significantly greater mean sum of skin-folds compared to children who watched less than 3 hours of television per day (106.2 millimetres (mm) versus 76.5 mm respectively).

Furthermore, there is evidence that TV viewing behavior in early childhood may predict TV viewing behavior and obesity in later childhood. Certain and Kahn (2002b) reported children who watched greater than 2 hours per day of television at age 2 years were more likely to watch greater than 2 hours per day at age 6 years. An analysis of the Avon longitudinal study revealed that children who spent more than 8 hours per week watching TV at the age of 3 years were 1.55 (1.13 to 2.12) times more likely to be obese at 7 years of age (Reilly et al., 2005b).

TV watching is thought to contribute to obesity by increasing sedentary time and decreasing physically active time, thus lowering habitual energy expenditure (Reilly et al., 2007; Reilly et al., 2008). This theory is supported by a study which found television watching was negatively correlated with physical activity levels in a sample of 3 and 4 year old children (DuRant et al., 1994). Television watching may also promote energy intake through exposure to food advertisements, increasing the consumption of unhealthy energy-dense foods (Taveras et al., 2006). A NZ study of 3,275 children aged 5 to 14 years found that children who watched the most TV were significantly more likely to be greater consumers of foods commonly advertised on TV including soft drinks, fruit drinks and some fast foods (Utter et al.,2006).

Summary of food and activity patterns

In summary, a number of food and activity patterns associated with childhood obesity have been identified. For example, the consumption of sugar sweetened drinks and time spent watching TV appear to increase the risk of childhood obesity, while the consumption of breads and cereals and time spent physically active appear to be protective. As food and activity patterns may track from early childhood into later childhood, establishing healthy patterns from a young age may be important for long-term health. Little is currently known regarding the food and activity patterns of young children in NZ, though there is evidence to suggest a high proportion of children have food intakes that are not consistent with the MoH guidelines. Further research is needed to examine food and activity patterns in young NZ children and associations with body composition, especially in ethnic groups such as Maori, Pacific, Indian and other Asian.

1.2.3 Maternal diabetes and childhood obesity

In addition to food and activity patterns, the intrauterine environment an individual is exposed to may influence their risk of childhood obesity, with a growing body of evidence suggesting the prenatal period is an important predictor of long-term health. The 'fetal origins of disease' hypothesis was first proposed by Barker and colleagues, who demonstrated a relationship between low birth weight and adult hypertension, dyslipidaemia and insulin resistance (Barker, 1997). This hypothesis formed the basis of research into 'developmental programming' or the 'Developmental Origins of Health and Disease' (DOHaD). Exposure to an altered intrauterine environment, as occurs with maternal undernutrition or overnutrition (such as maternal diabetes) may influence disease risk throughout the life course.

1.2.3.1 Maternal diabetes, glucose control and offspring obesity

Exposure to maternal diabetes (GDM and pre-existing T2DM) has been linked with an increased risk of obesity and T2DM in offspring in a number of studies. Silverman et al. (1991) at the Northwestern University Diabetes in Pregnancy Center carried out a long-term prospective evaluation of offspring exposed to maternal diabetes. Offspring from mothers with diabetes were large at birth, with 50% in the 90^{th} percentile of weight for gestational age, though weight returned to normal by 12 months. After 5 years of age, weight increased dramatically in the offspring of mothers with diabetes, and by 8 years 50% had weights in the 90^{th} percentile. Throughout adolescence, mean BMI in the affected offspring was 24.6 ± 5.8 kg/m² compared with 20.9 ± 3.4 kg/m² in control subjects (Silverman et al., 1998). In addition to obesity, one-third of the offspring of mothers with diabetes had evidence of impaired glucose tolerance or T2DM by the age of 17 years.

To examine the effect of a diabetic intrauterine environment on the risk of obesity and T2DM in offspring without confounding from inherited genetic factors, Dabelea et al. (2000) compared siblings where one was born before and one after the mother was diagnosed with T2DM, essentially differing only in their intrauterine environment. Mean BMI was 2.6 kg/m² higher in offspring exposed to maternal diabetes, compared with offspring born before their mother developed diabetes. The risk of T2DM was also higher in the offspring born after their mother developed diabetes, compared to those born before (OR 3.7).

Even exposure to milder levels of maternal hyperglycaemia, in the absence of overt diabetes, appears to be linked with an increased risk of obesity in offspring. In a prospective study of over 9400 offspring, Hillier et al. (2007b) found a positive trend for increasing childhood obesity between the ages 5 to 7 years across a range of increasing maternal glucose screen values – after adjustment for maternal weight, age, parity and birth weight. The risk of obesity was increased in offspring exposed to milder, untreated hyperglycaemia as opposed to offspring from mothers with diagnosed diabetes who received treatment.

Though the molecular mechanisms that underlie the programming of obesity and T2DM are beyond the scope of this thesis, it important to understand that fetal programming is thought occur via epigenetics rather than changes to actual DNA base sequence (Gluckman et al., 2008). Epigenetics refers to the mechanisms that lead to long term changes in the expression of a gene, such as gene silencing by methylation in the promoter region—a process involved in the differentiation of cells for different tissues. Vitamin B_{12} and folate are important methyl donors, and are essential for normal cell growth and division. Research now suggests these micronutrients may play a role in fetal programming. Genetically obese Agouti mice fed a methylating cocktail of vitamin B_{12}, folic acid, betaine and choline during pregnancy have offspring that are less obese and have a different coat colour – despite inheriting the Agouti mutation (Waterland et al., 2003).

A recent study in India demonstrated women with low B_{12} status had increased adiposity and a higher prevalence of insulin resistance and GDM compared to those with adequate B_{12} (Krishnaveni et al., 2009); while in the longitudinal Pune Maternal Nutritional Study, 6 year old offspring of women with high folate and low B_{12} concentrations during pregnancy had greater adiposity and insulin resistance than offspring whose mothers had normal B_{12} status (Yajnik et al., 2008). Vitamin B_{12} deficiency is common among Indian populations due to vegetarian dietary practices (Yajnik et al., 2006), and in theory could contribute to the high prevalence of excess adiposity and T2DM observed in Indian populations.

1.2.3.2 Programming of food and activity patterns

The interaction between the prenatal environment and the postnatal environment, and the relative importance of each in determining long-term disease risk, is not yet clear (World Health Organisation, 2002). Evidence from animal models suggests the prenatal nutritional environment may influence postnatal lifestyle factors such as food and activity patterns. Vickers et al. (2000) have demonstrated that rats exposed to a nutritionally limited prenatal environment are hyperphagic postnatally, and that hyperphagia increases with advancing age and is amplified by a hypercaloric diet. At the other end of the spectrum, offspring from rats fed a ‘junk-food’ diet during pregnancy (i.e. a diet high in fat, salt and sugar), showed an increased preference for junk-food postnatally, and had higher weights and BMI’s than offspring from rats fed standard chow diets during pregnancy (Bayol et al., 2007).

Postnatal activity also appears to be influenced by prenatal nutrition. Vickers et al (2003) demonstrated that rats born to nutritionally undernourished mothers were significantly less active than normal birthweight offspring at all ages studied (35 days, 145 days, and 420 days), and that sedentary behavior in the prenatally undernourished rats was exacerbated by postnatal hypercaloric nutrition. In contrast Miles et al (2009b) recently demonstrated that, when given a choice, rats born to nutritionally undernourished mothers show an increased preference for wheel running (exercise) over lever pressing for food (eating) compared with normal offspring.

Animal models have also provided evidence that the postnatal environment may in fact override the risks conferred by a nutritionally adverse prenatal environment (Gorski et al., 2006b). When rats from nutritionally undernourished pregnancies are exposed to a postnatal high fat diet, obesity is amplified (Krechowec et al., 2006), yet when they exposed to moderate daily exercise, the development of obesity is prevented (Miles et al., 2009a).

Studies examining the effect of prenatal undernutrition or overnutrition on postnatal food and activity patterns in humans are lacking. Whether postnatal exposures such as breastfeeding, as well as later diet and physical activity can modify the risk of obesity in the offspring of diabetic mothers is an area that requires further research. After an extensive literature search, not studies were found which examined the effect of exposure to maternal diabetes on food and activity patterns in offspring.

1.2.4 Review of methods

Methods used to measure food and activity patterns and body composition are reviewed in this section. As the author of this thesis was not involved in the study design, methods are reviewed in brief only.

1.2.4.1 Methods of measuring food and activity patterns

Two methods of measuring food patterns were used in this study: a 24-hour food recall and a semi-abbreviated food frequency questionnaire (FFQ). These methods were selected to reduce participant time and burden. Studies involving children under the age of 7 to 8 years rely on parental estimates of food intake, which appear to be an accurate measure of children's food intake in the home (Klesges et al., 1987; Eck et al., 1989; Basch et al., 1990; Baranowski et al., 1991) though may be less accurate when parents are reporting food consumed away from home (Baranowski et al., 1991).

Serdula et al (2001) reviewed of methods of measuring food consumption in preschool aged children from 12 food recall and nine FFQ validity studies (Serdula et al., 2001). They reported that FFQs in general, while easy to complete, can overestimate energy intake in preschoolers, and are more accurate in ranking rather than quantifying usual intake. FFQs must also be appropriate for the population they are administered in, taking into account for example the age and ethnicity of participants. Conversely, food recalls (such as 24-hour food recalls) do not need to be adjusted for different populations, however, they may require multiple days of collection to account for day-to-day variability in food intake. As the FFQ was based on food consumption patterns from a similar population of NZ children, and the aim of this study was examine food patterns, rather than quantify actual energy and nutrient intake, these methods appeared to be acceptable for use.

As with FFQs and food recalls, self-reported physical activity is a quick and inexpensive method of measuring physical activity in large numbers of participants. Limitations of using self or parent reported physical activity include reliance on respondent memory, and an inability to capture incidental activity (Dollman et al., 2009). Sallis et al. (2000) reviewed 17 studies of self-reported activity in children and adolescents (which included two studies of parent-reported activity in young children), concluding that all studies showed acceptable reliability, and some evidence of validity – with validity correlation ranging from 0.07 to 0.88 in self administered surveys, from 0.17 to 0.77 in interviews and 0.40 to 0.88 in parental recall of child activity.

1.2.4.2 Methods of measuring body composition

Obesity is defined as a condition of excessive fat accumulation to the extent that health and wellbeing may be impaired (World Health Organisation, 1998). Obesity is measured by a variety of methods and in a variety of different settings. Power et al (1997) state that 'an ideal measure of body should be accurate in its estimate of body fat; precise, with small measurement error; accessible, in terms of simplicity, cost and ease of use; acceptable to the subject; and well documented, with published reference values' and that 'no existing measure satisfies all these criteria'. Methods used to measure body composition in this study included anthropometry, bioimpedance analysis (BIA) and DEXA, reviewed below.

For measuring obesity in populations, BMI, a simple anthropometric measurement of weight in kilograms divided by height in meters squared is most commonly used, and has been shown to give a valid estimate of body fatness (Deurenberg et al., 1991). For adults, the WHO issued BMI cutoff points of 25 kg/m^2 and 30 kg/m^2 to define overweight and obesity respectively, based on the risks of related diseases at and above these BMI values (WHO Consultation on Obesity, 2000). Classifying obesity in children - who are constantly growing - is more difficult, as age needs to be taken into account. Based on the growth of 180,000 children from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the US, Cole et al. (2000) issued age-specific BMI cut-off points which correspond to the BMI values at each age that pass through thin ($<18.5 kg/m^2$), overweight (>25 kg/m^2) and obese (>30 kg/m^2) at 18 years of age.

Another method of assessing growth in children is by comparison with growth standards. Two growth standards are commonly used, the Centers for Disease Control (CDC) 2000 growth standards, and the WHO 2006 growth standards. The WHO 2006 growth standards are a series of percentile curves of selected measurements and are based on data from the WHO Multicentre Growth Reference Study (MGRS) (WHO Multicentre Growth Reference Study Group, 2006a; WHO Multicentre Growth Reference Study Group, 2006b). The MGRS was carried out between 1997 and 2003 and examined growth in children from Brazil, Ghana, India, Norway, Oman and the USA who were breastfed (exclusively or predominantly breastfed for at least 4 months and partially breastfed for up to 12 months) and from non-smoking, singleton pregnancies. A feature of growth standards is that the model allows z-scores (or SD scores) for height, weight and BMI to be determined based on the actual age and sex of each child.

However, BMI is only a surrogate marker of body fatness, and as mentioned previously there are ethnic differences in the ratio of lean to fat mass for a given body size. An alternative method for measuring body fatness is bioelectrical impedance analysis (BIA), a noninvasive and easily applied methodology for measuring body composition. In BIA a small constant current at a fixed frequency is passed through the body and opposition to the flow (impedance), by body fluids, is measured. This measurement is based on the assumption that the human body is essentially cylindrical, and can be divided into two compartments: lean and fat. Lean tissue contains most of the body water and as such is a good conductor of electricity, while fat contains little body water and is a poor conductor of electricity. In single-frequency BIA, surface electrodes are placed on the hand and foot and the drop in voltage between the electrodes provides a measurement of impedance to the flow of the current. BIA can be used to estimate fat free mass (FFM), and thus FM, in healthy subjects with a validated equation that is age, sex and ethnic specific (Kyle et al., 2004).

Compared with anthropometric and BIA measurements, DEXA is a more accurate yet more expensive and burdensome method of measuring body composition. It is based on the attenuation of x-rays passed through a supine body, with the intensity of the x-ray beam on the dorsal side of the body related to its thickness, density and chemical composition (Ellis, 2000). High energy and low energy x-rays are applied simultaneously and the relative absorption of fat, lean and bone tissue are assumed based on experimental studies. DEXA therefore provides a measure of FM, lean mass (LM) and bone mineral content (BMC). Total body mass (TBM) is calculated as the sum of FM, LM and BMC; and FFM is calculated as the sum of LM and BMC. Because DEXA is expensive and requires highly co-operative subjects, it may not be appropriate for widespread use on subjects under 6 years of age (Lobstein et al., 2004).

1.3 Aims

The primary aims of this study were to:

- Describe food and activity patterns in NZ toddlers and differences among ethnic groups. More specifically to describe:
  - Patterns of food and food group consumption
  - Patterns of daily food consumption
  - Patterns of daily activity
- Describe body size and body composition in NZ toddlers and differences among ethnic groups
- Determine food and activity patterns that are associated with adiposity and overweight or obesity in toddlers.

The secondary aims of this study were to:

- Determine whether food consumption and activity patterns in toddlers are affected by maternal glucose control during pregnancy.
- Determine whether food and activity patterns in toddlers are affected by maternal treatment for GDM (metformin versus insulin).

1.4 Hypotheses

The primary hypotheses were that:

- Overall, a high proportion of toddlers would not meet the MoH food and nutrition guidelines, and food and activity patterns would different among ethnic groups.
- Body composition would be different among ethnic groups. Polynesian toddlers would have higher BMI values than European toddlers, but have less FM for a given BMI. Conversely, Indian and Asian toddlers would have lower BMI values than European toddlers, but have more FM for a given BMI.
- Consumption of treat foods, sweet drinks and takeaways would be positively associated with FM, while the consumption of fruit, vegetables, meat and other protein, milk and dairy products, and breads and cereals would be inversely associated with FM.

- Time spent watching TV would be positively associated with FM in toddlers, while time spent sleeping and physically active would be inversely associated with FM.

The secondary hypotheses were that:

- There would be no differences in food and activity patterns by maternal treatment for GDM (metformin versus insulin).
- Children born to mothers with relatively poor glucose control during pregnancy would consume more treat foods, sweet drinks and takeaways, and spend more time in sedentary activities.

1.5 Significance

Little is known regarding the food and activity patterns of toddler and preschool children in NZ, and no studies have yet examined food and activity patterns in young NZ Indian children exclusively. As infancy and early childhood have been identified as important periods for obesity prevention throughout the life course, effective early life interventions are needed. This study provides essential information regarding the food and activity patterns of toddlers in NZ and differences among ethnic groups, which could be used to inform future interventions.

Ethnic differences in body size and body composition among children and adults are recognised and are likely to be associated with risk of chronic disease. This is the first NZ study to examine and compare differences in body size and body composition in a sample of children as young as 2 years using anthropometry and BIA. Furthermore, this is the first study to develop a BIA equation to predict FFM in a multiethnic sample of 2 year old children, validated by DEXA. As BIA equations tend to be specific for the population they were developed in, this equation could be used for future studies involving toddler and preschool children in the uniquely multiethnic population of NZ.

Animal studies have suggested the maternal nutritional environment affects food and activity patterns in offspring. To the author’s knowledge, this is the first study to examine the effect of maternal glucose control during pregnancy on food and activity patterns in offspring, and provides unique information on the relationship between the prenatal and postnatal environment. Identifying lifestyle factors such as food and activity patterns which may overcome the risk of obesity in these children is important, as the number of children exposed to maternal diabetes (and lower levels of maternal hyperglycaemia) looks set to rise in the upcoming years. As this study is a part of a longitudinal study, food and activity patterns and body composition information from this study can be compared with the future health and presence of disease risk factors in these children.

Finally, as the original MiG trial was carried out to assess the safety and efficacy of metformin as an alternative treatment to insulin for GDM, this study provides essential information regarding the effect of GDM treatment on postnatal food and activity patterns in offspring.

CHAPTER 2: DESIGN AND METHODS

A brief overview of the study is presented in this chapter, followed by methods of data collection, methods of data processing and methods of statistical analysis.

The study contained in this thesis is part of an ongoing longitudinal study. The work undertaken by the author of this thesis included: entry and coding of the 24-hour food recalls and data analysis and interpretation of 24-hour food recalls, 24-hour activity recalls, FFQ and body composition. The author was not involved in the design of the methods or in data collection, though did attend measurement sessions in the latter stages of the study.

2.1 Overview

The MiG trial randomized women with GDM to metformin or insulin therapy during pregnancy, with aim of showing metformin is a safe and effective alternative treatment to insulin (Rowan et al., 2008). This trial recruited women between 2002 and 2006. MiGTOFU is a longitudinal study following the offspring of mothers who participated in the MiG trial. Ethical approval was received from the Northern Regional Ethics Committee.

Of the 750 women with GDM who participated in the MiG trial, 396 were recruited in Auckland and gave consent for follow up. These women were contacted every 6 to 12 months. When the child was 2 years old, an information sheet and consent form regarding participation in MiGTOFU was sent. Assessments of the children at 2 years of age were carried out between October 2004 and June 2009.

Assessments were performed at the child's home and the Liggin's Institute, with assessors blind to the treatment the mother received. They involved measurements of body composition (by anthropometry, BIA and DEXA), food and activity patterns (parental 24-hour food and activity recall, and an FFQ), neurodevelopment (Bayley's II Development Score, administered by a psychologist), and a physical examination performed by a paediatrician. Maternal anthropometric measurements were also taken at this time. Only body composition and food and activity measurements are addressed in this thesis.

Trained researchers visited consenting participants at their home. During this visit, an FFQ (included in Appendix 2) and a 24-hour food and activity recall (included in Appendix 3) were administered to the child's mother or guardian and anthropometry and BIA were performed on the child. Participants were then asked to visit the Liggin's Institute, where a DEXA scan was performed on co-operative children. Any measurements that were not completed during the home visit were repeated at this time, and a separate researcher reviewed the questionnaire to ensure it was completed correctly.

All data collected from the 2 year old assessments, with the exception of the 24-hour food recall, was entered into the Green Lane Coordinating Centre (GLCC) database (GLCC Research Organisation Ltd., 2010), which linked to the MiG database. The MiG database contained information collected during pregnancy, including variables used in this study: the treatment the mother received during pregnancy, her glucose control, the child's ethnicity and the child's date of birth.

Methods of data collection, data processing and statistical analysis are described below. As the author of this thesis was only involved in the data processing and statistical analysis, data collection is described only in brief. The author did observe a number of measurement occasions at the Liggin's Institute in the latter stages of the study.

2.2 Data collection

2.2.1 Baseline data collection

Baseline data refers to data collected during the MiG trial and includes: maternal GDM treatment (metformin or insulin), maternal glucose control (recorded as tertile 1, 2 or 3, described in further detail below), ethnicity (identified by the child's parents as European, Maori, Pacific, Indian, Chinese, Other Asian or Other) and date of birth.

Maternal glucose control measurements

All capillary glucose measurements from recruitment into the MiG trial until delivery were prospectively recorded into the MiG database. Maternal glucose was measured fasting and 2 hours after breakfast, lunch and dinner each day by a Medisense capillary glucose monitor. Mean fasting and postprandial glucose control was calculated in each individual. Overall glucose control was calculated by adding the mean fasting and mean postprandial glucose results and dividing by two. Glucose control was then divided into tertiles, with tertile 1 being the lowest levels (best control) and tertile 3 being the highest levels (worst control). For these analyses, the overall mean glucose control was used.

2.2.2 Food and activity data collection

Food and activity data were collected on a visit to the child's home. Trained researchers assisted the child's mother in completing a semi-abbreviated FFQ, a 24-hour food recall and a 24-hour activity recall. Researchers followed a standard protocol included in a study manual.

Food frequency questionnaire

The semi-abbreviated FFQ (Appendix 2) was developed with the assistance of a paediatric dietician and was based on the results of the CNS pilot study, which included European, Maori and Pacific children aged 1 to 4 years. The FFQ included 66 individual food items. Mothers were asked to estimate how often their child consumed each food out of the following options: never, once a month, once a week, two to four times weekly, five to seven times weekly, two to three times a day and four or more times a day. They were asked to record the brand name of the food where applicable.

FFQ data was entered into the GLCC data base.

Twenty four -hour food recall

Mothers were asked to recall the type and amount of food and drink their child usually consumes during a typical 24-hour period (6am to 6am), and at what time they consume it.

Twenty-four hour food recall questionnaires were stored for analysis (not entered into the GLCC database).

Twenty-four activity recall

Mothers were asked to recall which of six activities their child typically engages in for each hour over a 24-hour period (6am to 6am) The six activity options were as follows: sleeping, TV or video, sitting, quiet play, physically active or other. The total of all six options had to equate to 24 hours.

Twenty-four hour activity recall data was entered into the GLCC database by summing the total number of hours the child spent in each of the six activity options, and the time they awoke in the morning and went to bed at night.

2.2.3 Body composition data collection

Body composition was measured by anthropometry and BIA at the child's home. When children were cooperative, DEXA scans were also performed at the Liggin's Institute. Researchers followed a standard protocol included in a study manual.

Anthropometry

Height and weight were measured at the child's home and repeated at the Liggin's Institute if necessary (i.e. the child was not cooperative on the home visit). Two readings (to the nearest 0.1 cm and 0.1 kg) were made for each measurement and the average of the two used. A third measurement was carried out of the difference between the first two height measurements was greater than 0.5cm, or weight measurements greater than 0.5kgs. In this case, the average of the three measurements was used.

Bioimpedance analysis

BIA was performed at the child's home. Single-frequency (50kHz) BIA was performed using a battery-operated bioimpedance analyser (BIM4, Impedimed, Queensland, Australia). Areas on the hand and foot where electrodes were to be placed were first cleaned with alcohol. The current electrodes were placed on the hand on the distal portion of the second metacarpal, and on the foot over the distal portion of the second metatarsal. The sensing electrodes were placed at the anterior ankle between the tibial and fibular malleoli and at the posterior wrist between the styloid processes of the radius and ulna. The measurements were repeated up to three times until they were stable to within one ohm. The average value was used.

Dual energy x-ray absorptiometry

DEXA scans were performed by a trained researcher on co-operative children using a single DEXA machine (Lunar Prodigy 2000, General Electric, Madison, WI, software version 4.80x6.50) at the Liggin's Institute. Children were measured wearing a dry nappy or underpants, and a t-shirt. As a means of quality control, all scans were reviewed by one researcher (Professor Elaine Rush) and given a grade of A, B or C depending on their quality.

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2.3 Data processing

Data from the FFQ, 24-hour activity recall, anthropometric measurements, BIA and DEXA, as well as background data from the MiG trial (sex, age, ethnicity, birthweight, maternal GDM treatment and maternal glucose control during pregnancy) were imported from the GLCC database into an Excel^{TM} spreadsheet for analysis. Twenty-four hour food recalls were categorised (e.g. foods and number of meal occasions, detailed in the next section) from the raw data by the author of this thesis and entered in an Excel^{TM} spreadsheet.

2.3.1 Baseline data processing

Maternal GDM treatment, glucose control during pregnancy, and the sex and age of the child were used as entered into the GLCC data base.

The author of this thesis further categorized children into five ethnic groups (European, Polynesian, Indian, Asian and Other). Because the number of Maori participants was so small (n = 5), Pacific and Maori children were combined into one ethnic group (Polynesian). Similarly, because the number of Chinese (n = 12) and other Asian (n = 6) participants were so small, Chinese and Asian children were combined into one ethnic group (Asian).

2.3.2 Food and activity data processing

Food frequency questionnaire

A total of 147 participants completed FFQs. Individual missing values for each food or food group were coded as missing and numbers stated in the analyses. FFQ data on 66 individual food items was converted into times per day by taking the mid-point of the frequency option and dividing by 28 if the frequency option was per month or seven if the frequency option was per week. For example, the option ‘two to four times per week’ was converted to times per day by taking the mid-point three, and dividing by seven to give 0.43 times per day.

To allow for comparison with the MoH guidelines, the following food groups were created by summing the total number of times children consumed the following foods each day.

- **Fruit** (fresh fruit, dried fruit, tinned fruit in syrup and tinned fruit in juice)
- **Vegetables** (green vegetables, red/orange vegetables, potato boiled, potato mashed, kumara, taro, plantain and other vegetables)
- **Breads and cereals** (white bread, smooth brown bread smooth, grainy brown bread, white rice, brown rice, dumplings, noodles, pasta, roti, chappati, naan, unsweetened breakfast cereal and sweetened breakfast cereal)

- **Milk and dairy products** (standard full-fat milk, reduced fat milk, low-fat milk, sweetened milk, cheese, cheese sauce, unsweetened yogurt and sweetened yoghurt)
- **Meat** (red meat, other meat, fish, fish fingers and processed meat)
- **Meat and other protein** (red meat, other meat, fish, fish fingers, processed meat, eggs, lentils and beans)
- **Other drinks** (formula, breast milk, tea and coffee with sugar, tea and coffee without sugar and soy milk).
- **Treat foods** (biscuits plain, biscuits choc icing, muesli bar, chocolate bar, lollies and crisps)
- **Sweet drinks** (juice and sugar sweetened beverages)
- **Takeaways and fries** (potato fries, pizza, McDonald's/Burger King, Kentucky Fried Chicken, fish and chips, Chinese takeaway, Indian takeaway and other takeaway).

The number and percentage of children consuming each of the following food groups in line with MoH recommendations (see Appendix 1 for MoH food and nutrition guidelines) were calculated: fruit, vegetables, breads and cereals, milk and dairy products, meat and meat and other protein. To determine the amount of high-fat and high-sugar foods children were consuming, the number and percentage of children consuming the following food groups daily or weekly were calculated: treat foods, sweet drinks and takeaways and fries.

From the FFQ individual foods were ranked within each food group by the number (percentage) of children who reported consuming them at least twice a week. Some foods were presented individually as well as combined into one overall food category, for example total bread was calculated by the summing the number of children who consumed white bread, smooth brown bread and grainy brown bread at least twice a week, and total yoghurt was calculated by summing the number of children who consumed sweetened yoghurt and unsweetened yoghurt at least twice a week.

As the amount of food consumed was not measured, 'times per day' rather than 'servings per day' are presented.

Twenty-four hour food recall

A total of 147 children completed 24-hour food recalls. 24-hour food recalls were analysed separately by the author of this thesis.

Due to time constraints and/or problems with communication, the 24-hour food recalls did not always contain information regarding the amount or type of food consumed, for example, ‘milk’ was often recorded on 24-hour recalls instead of ‘250 ml of low-fat milk’, or ‘rice/noodles’ was recorded instead of ‘1/2 cup of white rice’. Therefore, to ensure consistency in the analysis of the 24-hour food recalls, varieties of foods were grouped, for example, all types of milk (except for sweetened milk) formed one category ‘milk’ and rice, noodles and pasta formed one category ‘rice, noodles and pasta’.

Whether or not a child consumed each food at each meal was recorded. Foods consumed as the first meal of the day were recorded as breakfast; foods consumed as part of a main meal at midday and the end of the day were recorded as lunch and dinner respectively; foods consumed between breakfast and lunch were recorded as a morning snack; foods consumed between lunch and dinner were recorded as an afternoon snack, and foods consumed between dinner and breakfast were recorded as an evening snack. Dessert type foods eaten with dinner (e.g. ice cream) were recorded as dinner. Whether or not a child consumed different types of drinks at least once during the day was also recorded.

Individual foods were ranked by the number (percentage) of children consuming them at least once during a typical day, and by the number and percentage of children consuming them at each of the five meals.

2.3.3 Body composition data processing

All 147 children for which food consumption and activity data were available also completed height and weight measurements. BMI was calculated from height and weight measurements (weight kg / height m^2). Height, weight and BMI were converted into weight-for-age, height-for-age and BMI-for-age z-scores based on the 2006 WHO growth standards, using LMS growth add in (LMS growth add in by Tim Cole, downloaded from http://www.healthforallchildren.co.uk/) in an Excel™ spreadsheet. One child was an outlier (BMI z-score < - 3.6) and was removed from the data set, bringing the total number of participants for which height, weight and BMI measurements were presented to 146.

Of these 146 children, 77 also completed high quality (A or B grade) DEXA scans. DEXA TBM was calculated as the sum of LM, FM and BMC. DEXA FFM was calculated as the sum of LM and BMC. DEXA FFM was used to validate an equation to predict FFM from BIA (resistance), height, weight, age and sex measurements. Details of the equation are included in Appendix 4.

The DEXA equation was applied to all 146 children from the total sample to calculate FFM. FM was calculated by subtracting FFM from the child's measured weight. Body fat percent (%BF) was calculated by dividing FM by the child's measured weight and multiplying by 100. Two children were outliers (biologically implausible %BF of less than 5%) and were removed from the data set, bringing the total number of participants for which FM, FFM and %BF measurements were presented to 144.

2.4 Statistical analyses

SPSS version 14.0 (SPSS Inc, Chicago, IL) was used for the statistical analysis. The significance level was set at 0.05 (5%).

Continuous variables were examined whether they had normal distributions and for all data presented the distribution were normal. Continuous variables are presented as mean ± SD. One-way analysis of variance (ANOVA) was used to test for differences in group means, and post-hoc t-tests used to determine which groups were significantly different. Analysis of co-variance (ANCOVA) was used to adjust for height, weight and age when examining differences in FM and FFM among ethnic groups.

Because of the number of tests carried out when examining associations between food and activity patterns, body composition and maternal glucose control, the significance level was set at 0.01 (1%) to reduce the chance of a type I error (a false positive result).

Categorical variables are presented as frequency and percentage. Differences between frequencies were examined by the use of 95% CI, determined as follows: standard error (SE) of percentage response of interest (% response) = √ (% response * (100 - % response)) / number of responses; width of the 95% CI = 1.96 * SE; upper 95% CI = % response + 95% CI; and lower 95% CI limit = % response – 95% CI. Frequencies were significantly different if their CI did not overlap. The chi-squared test was applied to determine linear associations with categorical scales/ranks and differences between bivariate categorical variables.

CHAPTER 3: RESULTS

The results chapter has been divided into three sections, preceded by a short baseline information section. Patterns of food and food group consumption, patterns of daily food consumption and patterns of daily activity are presented in section A; height, weight and BMI; height, weight and BMI z scores; and FM, FFM and %BF are presented in section B; and associations between food and activity patterns and body composition, and associations between maternal GDM treatment, each section information is presented first for the total sample, and by sex and ethnicity where applicable.

3.1 Baseline information

Table 3.1 presents the baseline characteristics of children, by sex and ethnicity. The sample of children examined in this study consisted of 33% European, 28% Polynesian, 25% Indian, 12% Asian and 3% Other children, and similar amount of boys and girls. The average age of children was 27.7 ± 2.8 months. Of children in the total sample, significantly more Polynesian than European and Indian children were born to mothers in the worst glucose control tertile (tertile 3) and significantly more European and Indian than Polynesian children were born to mothers in the best glucose control tertile (tertile 1).

Table 3.1 Baseline characteristics of the study population by sex and ethnicity

	European	Polynesian	Indian	Asian	Other	Total
Girls						
n	26 (32.5)	22 (27.5)	17 (21.2)	12 (15.0)	3 (3.8)	80 (54.4)
Age*	26.5 ± 2.5	28.2 ± 3.0	27.1 ± 2.4	27.6 ± 2.7	28.3 ± 4.2	27.4 ± 2.7
Glucose control						
Tertile 1	16 (61.5)	3 (13.6)	5 (29.4)	5 (41.7)	1 (33.3)	30 (37.5)
Tertile 2	7 (26.9)	9 (40.9)	8 (47.1)	4 (33.3)	1 (33.3)	29 (36.2)
Tertile 3	3 (11.5)	10 (45.5)	3 (23.5)	3 (25.0)	1 (33.3)	21 (26.2)
GDM treatment						
Insulin	12 (46.2)	12 (54.5)	9 (52.9)	8 (66.7)	2 (66.7)	43 (53.8)
Metformin	14 (53.8)	10 (45.5)	8 (47.1)	4 (33.3)	1 (33.3)	37 (46.2)
Boys						
n	22 (32.8)	19 (28.4)	19 (28.4)	6 (9.0)	1 (1.5)	67 (45.6)
Age*	27.4 ± 2.1	28.1 ± 2.4	29.1 ± 3.6	27.0 ± 2.7	30.1	28.1 ± 2.8
Glucose control						
Tertile 1	8 (36.4)	3 (15.8)	13 (68.4)	2 (33.3)	1 (100.0)	27 (40.3)
Tertile 2	12 (54.5)	8 (42.1)	5 (26.3)	2 (33.3)	0 (0.0)	27 (40.3)
Tertile 3	2 (9.1)	8 (42.1)	1 (5.3)	2 (33.3)	0 (0.0)	13 (19.4)
GDM treatment						
Insulin	13 (59.1)	9 (47.4)	12 (63.2)	2 (33.3)	1 (100.0)	37 (55.2)
Metformin	9 (40.9)	10 (52.6)	7 (36.8)	4 (66.7)	0 (0.0)	30 (44.8)
Total						
n	48 (32.7)	41 (27.9)	36 (24.5)	18 (12.2)	4 (2.7)	147 (100.0)
Age*	26.9 ± 2.4	28.2 + 2.7	28.2 ± 3.2	27.4 ± 2.6	28.8 ± 3.6	27.7 ± 2.8
Glucose control						
Tertile 1	24 (50.0)†	6 (14.6)	18 (50.0)†	7 (38.9)	2 (50.0)	57 (38.8)
Tertile 2	19 (39.6)	17 (41.5)	13 (36.1)	6 (33.3)	1 (25.0)	56 (38.1)
Tertile 3	5 (10.4)	18 (43.9)‡§	5 (13.9)	5 (27.8)	1 (25.0)	34 (23.1)
GDM treatment						
Insulin	25 (52.1)	21 (51.2)	21 (58.3)	10 (55.6)	3 (75.0)	80 (54.4)
Metformin	23 (47.9)	20 (48.8)	15 (41.7)	8 (44.4)	1 (25.0)	67 (45.6)

* Age values are mean ± SD, for all other variables values are number (percent); Glucose control tertile: tertile 1 = best glucose control, tertile 3 = worst glucose control; † Significantly greater than Polynesian; ‡ Significantly greater than European; § Significantly greater than Indian.

3.2 Section A: Food and activity patterns

No significant differences were found in food and activity patterns between boys and girls, and information is therefore presented for the total sample and by ethnicity only. Food and activity data are not presented separately for the Other ethnic group due to the small number of participants (n = 4).

3.2.1 Patterns of food and food group consumption from the FFQ

3.2.1.1 Fruit and vegetables

Overall, 34% and 24% of children did not consume fruit twice a day as recommended by the MoH (Table 3.2). Significantly less Indian than European children consumed fruit at least twice a day. Less Indian than European children also consumed vegetables at least twice a day, although the difference was not significant.

Fresh fruit was the most popular fruit consumed, followed by dried fruit, with significantly more European children consuming dried fruit at least twice a week than any other ethnic group. Red or orange vegetables and green vegetables were the most popular types of vegetables consumed. Significantly more Polynesian children consumed taro at least twice a week than all other groups, and potatoes at least twice a week than Asian children. No other ethnic differences in the number of children consuming types of fruits and vegetables were observed.

Table 3.2 Number of children consuming total fruits and vegetables at least twice a day and different varieties of fruits and vegetables at least twice a week by ethnicity, from an FFQ

Food / food group	Freq.	Total (n = 147)	m	European (n = 48)	m	Polynesian (n = 41)	m	Indian (n = 36)	m	Asian (n = 18)	m
All fruit	**≥ 2 day****	**94 (65.7)**	**4**	**36 (76.6)***	**1**	**28 (71.8)**	**2**	**15 (42.9)**	**1**	**12 (66.7)**	**0**
Fresh fruit	≥ 2 week	141 (95.9)	0	45 (93.8)	0	39 (95.1)	0	36 (100.0)	0	17 (94.4)	0
Dried fruit	≥ 2 week	73 (50.0)	1	37 (77.1)*†‡	0	11 (27.5)	1	17 (47.2)	0	6 (33.3)	0
Canned fruit in juice	≥ 2 week	32 (22.4)	4	19 (39.6)	1	6 (15.4)	2	5 (14.3)	1	2 (11.1)	0
Canned fruit syrup	≥ 2 week	11 (7.7)	4	4 (8.5)	1	4 (10.3)	2	2 (5.7)	0	1 (5.6)	0
All vegetables	**≥ 2 day****	**107 (76.4)**	**7**	**38 (80.9)**	**1**	**32 (82.1)**	**2**	**20 (60.6)**	**3**	**14 (82.4)**	**1**
Red or orange vegetables	≥ 2 week	132 (91.0)	2	44 (91.7)	0	37 (92.5)	1	31 (88.6)	1	16 (88.9)	0
Green vegetables	≥ 2 week	129 (88.4)	1	44 (91.7)	0	33 (82.5)	1	32 (88.9)	0	16 (88.9)	0
Other vegetables	≥ 2 week	76 (53.9)	6	31 (66.0)	1	18 (46.2)	2	15 (44.1)	2	10 (58.8)	1
Potatoes	≥ 2 week	71 (48.6)	1	24 (50)	0	26 (63.4)‡	0	12 (34.3)		5 (27.8)	0
Kumara	≥ 2 week	22 (15.0)	0	10 (20.8)	0	8 (19.5)	0	2 (5.6)	0	2 (11.1)	0
Taro	≥ 2 week	8 (5.4)	0	0 (0.0)	0	7 (17.1)†‡§	0	0 (0.0)	0	0 (0.0)	0
Plantain	≥ 2 week	6 (4.1)	0	0 (0.0)	0	3 (7.3)	0	2 (5.6)	0	1 (5.6)	0

Values are number (percent); m = missing values; Freq. = frequency; ** MoH recommended number of servings per day for 2 year old children; Cells where 95%CI (not reported) do not overlap have been highlighted as significant; * Significantly greater than Indian; † significantly greater than Polynesian; ‡ significantly greater than Asian; § significantly greater than European .

3.2.1.2 Breads and cereals

Overall, 64% of children in the total sample did not consume breads and cereals (which also included rice, noodles, pasta, roti, chappati, dumplings and naan) four or more times per day (Table 3.3). Of all ethnic groups, the highest percentage of Indian children consumed breads and cereals four or more times per day, although the difference was not significant.

Bread, breakfast cereal and rice were the most popular foods in the breads and cereals group, eaten at least twice a week by more than 90%, 80% and 70% of children respectively. White bread was the most commonly consumed bread, eaten by more than 60% of children at least twice a week, followed by smooth brown bread and grainy brown bread. Significantly more Pacific than Indian children ate white bread at least twice a week, while significantly more European children than Polynesian children ate grainy brown bread this often.

Non-sugary breakfast cereal was eaten at least twice a week by more than 75% of children, while only 20% ate sugary breakfast cereal this often. Significantly more European and Polynesian children consumed all breakfast cereals and non-sugary breakfast cereal at least twice a week than Asian children.

Almost 70% of children ate white rice at least twice a week, while less than 5% consumed brown rice this often. Significantly more Asian and Indian children consumed all rice and white rice at least twice a week than European children.

Noodles and pasta were consumed by close to 40% of children twice a week. Significantly more Asian and Polynesian children than European children consumed noodles, while significantly more European children than any other ethnic group consumed pasta at least twice a week. Roti and chappati were consumed almost exclusively by Indian children.

Table 3.3 Number of children consuming total breads and cereals at least four times a day and different varieties of breads and cereals at least twice a week by ethnicity, from an FFQ

Food / food group	Freq.	Total (n = 147)	m	European (n = 48)	m	Polynesian (n = 41)	m	Indian (n = 36)	m	Asian (n = 18)	m
All breads and cereals††	**≥ 2 day****	**52 (36.1)**	**3**	**14 (29.2)**	**0**	**12 (30.8)**	**2**	**18 (50.0)**	**0**	**7 (38.9)**	**0**
Bread	≥ 2 week	136 (93.2)	1	48 (100.0)	0	40 (100.0)	1	29 (80.6)	0	15 (83.3)	0
White bread	≥ 2 week	91 (62.3)	1	28 (58.3)	0	34 (85.0)*	1	13 (36.1)	0	13 (72.2)	0
Smooth brown bread	≥ 2 week	61 (41.5)	0	20 (41.7)	0	21 (51.2)	0	12 (33.3)	0	8 (44.4)	0
Grainy brown bread	≥ 2 week	54 (36.7)	0	26 (54.2)*	0	10 (24.4)	0	12 (33.3)	0	5 (27.8)	0
Breakfast cereal	≥ 2 week	122 (83.0)	0	42 (87.5)†	0	37 (90.2)†	0	30 (83.3)	0	9 (50.0)	0
Non-sugary breakfast cereal	≥ 2 week	112 (76.2)	0	40 (83.3)†	0	35 (85.4)†	0	25 (69.4)	0	8 (44.4)	0
Sugary breakfast cereal	≥ 2 week	32 (21.8)	0	9 (18.8)	0	11 (26.8)	0	10 (27.8)	0	1 (5.6)	0
Rice	≥ 2 week	104 (70.7)	0	24 (50.0)	0	26 (63.4)	0	32 (88.9)‡	0	18 (100.0)‡§	0
White rice	≥ 2 week	102 (69.4)	0	23 (47.9)	0	26 (63.4)	0	31 (86.1)‡	0	18 (100.0)‡§	0
Brown rice	≥ 2 week	6 (4.1)	0	1 (2.1)	0	1 (2.4)	0	2 (5.6)	0	2 (11.1)	0
Noodles	≥ 2 week	60 (40.8)	0	10 (20.8)	0	25 (61.0)†	0	12 (33.3)	0	12 (66.7)†	0
Pasta	≥ 2 week	54 (37.0)	1	29 (60.4)*†	0	11 (27.5)	1	4 (11.1)	0	6 (33.3)	0
Roti	≥ 2 week	25 (17.1)	1	0 (0.0)	0	1 (2.4)	0	24 (66.7)†‡§	0	0 (0.0)	0
Chappati	≥ 2 week	13 (8.9)	1	1 (2.1)	0	0 (0.0)	0	12 (33.3)†‡§	0	0 (0.0)	0
Dumplings	≥ 2 week	3 (2.0)	0	0 (0.0)	0	0 (0.0)	0	0 (0.0)	0	3 (16.7)	0

Values are number (percent); m = missing values; Freq. = frequency; ** MoH recommended number of servings per day for 2 year old children; †† total breads and cereals also includes naan (numbers not reported); Cells where 95% CI (not reported) do not overlap have been highlighted as significant; * Significantly greater than Indian, † Significantly greater than Asian; ‡ Significantly greater than European; § Significantly greater than Polynesian.

3.2.1.3 Meat and other protein

Overall, 23% of children in the total sample did not eat meat (red meat, other meat, processed meat, fish and fish fingers) once a day (Table 3.4). Less than half of Indian children ate meat once per day, significantly less than the number of European and Polynesian children. When other protein foods (eggs, lentils and beans) were included in this category, the number of children who did not eat meat or other protein once a day, as recommended by the MoH, declined to 7%. There were no significant differences among ethnic groups in the number of children consuming at least one serving of meat or other protein each day.

Other meat (for example, chicken and pork) and red meat were the most popular meats consumed, with around 70% of children consuming each at least twice a week. Significantly more European and Polynesian than Indian children consumed other meat and red meat at least twice a week. Processed meat was consumed by 36% of children overall at least twice a week, and again, significantly more European and Polynesian than Indian children consumed processed meat at least twice a week. Significantly more Asian than European children consumed fish at least twice a week.

Overall, 65% of children consumed another protein food (eggs, lentils or beans) at least twice a week, with eggs the most popular other protein food. Significantly more Asian children consumed all other protein foods at least twice a week than European and Polynesian children, and eggs twice a week than all other ethnic groups. Significantly more Indian children consumed lentils at least twice a week than all other ethnic groups.

Table 3.4 Number of children consuming total meat and other protein at least once a day and different varieties of meat and other protein at least twice a week by ethnicity, from an FFQ

Food / food group	Freq.	Total (n = 147)	m	European (n = 48)	m	Polynesian (n = 41)	m	Indian (n = 36)	m	Asian (n = 18)	m
All meat	**≥ 1 day**	**110 (76.9)**	**4**	**45 (95.7)***	**1**	**33 (84.6)***	**2**	**15 (42.9)**	**1**	**13 (72.2)**	**0**
All meat and other protein	**≥ 1 day**	**131 (92.9)**	**6**	**45 (95.7)**	**3**	**34 (89.5)**	**3**	**31 (88.6)**	**1**	**18 (100.0)**	**0**
Other meat	≥ 2 week	104 (71.7)	2	40 (83.3)*	0	29 (72.5)*	1	16 (45.7)	1	16 (88.9)	0
Red meat	≥ 2 week	101 (69.7)	2	44 (91.7)*	0	30 (75.0)*	1	12 (34.3)	1	11 (61.1)	0
Processed meat	≥ 2 week	52 (36.4)	4	22 (46.8)*	1	17 (43.6)*	2	6 (17.1)	1	5 (27.8)	0
Fish	≥ 2 week	30 (20.5)	1	6 (12.5)	0	9 (22.0)	0	5 (14.3)	1	9 (50.0)†	0
Fish fingers	≥ 2 week	14 (9.7)	2	2 (4.2)	0	6 (15.4)	2	3 (8.3)	0	3 (16.7)	0
Other protein	≥ 2 week	93 (65.0)	4	27 (57.4)	1	21 (53.8)	2	26 (72.2)	0	16 (88.9)†‡	0
Eggs	≥ 2 week	73 (50.3)	2	20 (42.6)	1	20 (50.0)	1	14 (38.9)	0	16 (88.9)*†‡	0
Beans	≥ 2 week	30 (20.4)	0	10 (20.8)	0	9 (22.0)	0	8 (22.2)	0	2 (11.1)	0
Lentils	≥ 2 week	25 (17.4)	3	3 (6.2)	0	2 (4.9)	0	19 (52.8) *†§	0	3 (16.7)	0

Values are number (percent); m = missing values; Freq. = frequency; ** MoH recommended number of servings per day for 2 year old children; Cells where 95% CI (not reported) do not overlap have been highlighted as significant; * Significantly greater than Indian; † Significantly greater than European; ‡ Significantly greater than Polynesian; § Significantly greater than Asian.

3.2.1.4 Milk and dairy products

Overall, 16% of children did not consume milk or dairy products twice a day, as recommended by the MoH (Table 3.5). Of all ethnic groups, the least amount of Asian children consumed milk and dairy products at least twice a day, although the difference was not significant.

Milk was the most commonly consumed dairy product, followed by yoghurt and cheese. Over 90% of children consumed milk at least twice a week, with full-fat milk the most popular variety, followed by sweetened milk, reduced-fat milk and lastly, low-fat milk. Polynesian and Indian children were the greatest consumers of sweetened milk, with significantly more Polynesian children consuming sweetened milk at least twice a week than European and Asian children and significantly more Indian children consuming sweetened milk twice a week than Asian children.

There were no differences in the numbers of children consuming yoghurt at least twice a week, although significantly more European children consumed sweetened yoghurt than Indian children. Cheese was consumed at least twice a week by significantly more European than Polynesian children.

Table 3.5 Number of children consuming total milk and dairy products at least twice a day, and different varieties of milk and dairy products at least twice a week by ethnicity, from an FFQ

Food / food group	Freq.	Total (n = 147)	m	European (n = 48)	m	Polynesian (n = 41)	m	Indian (n = 36)	m	Asian (n = 18)	m
All milk and dairy products	**≥ 2 day**	**119 (83.8)**	**5**	**41 (87.2)**	**1**	**33 (84.6)**	**2**	**31 (88.6)**	**1**	**10 (55.6)**	**0**
Milk	≥ 2 week	136 (92.5)	0	47 (97.9)*	0	39 (95.1)	0	34 (94.4)		13 (72.2)	0
Full-fat milk	≥ 2 week	106 (72.1)	0	32 (67.7)	0	30 (73.2)	0	30 (83.3)	0	11 (61.1)	0
Sweetened milk	≥ 2 week	61 (41.5)	0	12 (25.0)	0	25 (61.0)*†	0	19 (52.8)*	0	3 (16.7)	0
Reduced-fat milk	≥ 2 week	28 (19.0)	0	12 (25.0)	0	11 (26.8)	0	4 (11.1)	0	1 (5.6)	0
Low-fat milk	≥ 2 week	14 (9.5)	0	8 (16.7)	0	4 (9.8)	0	2 (5.6)	0	0 (0.0)	0
Yoghurt	≥ 2 week	112 (78.3)		42 (89.4)	1	29 (74.4)	2	25 (71.4)	1	13 (77.2)	0
Sweetened yoghurt	≥ 2 week	93 (63.3)	4	39 (83.0)§	1	25 (64.1)	2	15 (42.9)	1	11 (61.1)	0
Unsweetened yoghurt	≥ 2 week	32 (22.4)	4	6 (12.8)	1	6 (15.4)	2	14 (40.0)	1	4 (22.2)	0
Cheese	≥ 2 week	100 (68.5)	1	42 (87.5)‡	0	22 (53.7)	0	25 (69.4)	0	10 (55.6)	0
Cheese sauce	≥ 2 week	6 (4.2)	5	4 (8.5)	1	1 (2.6)	2	1 (2.9)	1	0 (0.0)	0

Values are number (percent); m = missing values; ** MoH recommended number of servings per day for 2 year old children; Cells where 95% CI (not reported) do not overlap have been highlighted as significant; * Significantly greater than Asian; † Significantly greater than European; ‡ Significantly greater than Polynesian; § Significantly greater than Indian.

3.2.1.5 Other drinks

Significantly more Asian children consumed formula at least twice a week than any other ethnic group, with 60% reporting consumption (Table 3.6). Overall, 10% of children in the total sample consumed tea or coffee at least twice a week. Less than half the number of European children consumed tea or coffee at least twice a week than children from other ethnic groups, although the difference was not significant. Less than 10% of children in the total sample was breastfed at 2 years of age. Although the difference was again not significant, more Polynesian and Indian children were breastfed at least twice a week than European and Asian children.

Table 3.6 Number of children consuming other drinks at least twice a week by ethnicity, from an FFQ

Food / food group	Freq.	Total (n = 147)	m	European (n = 48)	m	Polynesian (n = 41)	m	Indian (n = 36)	m	Asian (n = 18)	m
Formula	**≥ 2**	27 (18.5)	1	9 (18.8)	0	2 (5.0)	1	5 (13.9)	0	11 (61.1)*†§	0
Tea or coffee	≥ 2	15 (10.2)	2	2 (4.2)	0	5 (12.2)	0	5 (13.9)	0	2 (12.5)	2
Tea or coffee with sugar	≥ 2	9 (6.1)	0	0 (0.0)	0	3 (7.3)	0	4 (11.1)	0	1 (5.6)	0
Tea or coffee without sugar	≥ 2	7 (4.8)	2	2 (4.2)	0	2 (4.9)	0	1 (2.8)	0	2 (11.1)	0
Breast milk	≥ 2	12 (8.2)	1	2 (4.2)	0	5 (12.5)	1	4 (11.1)	0	0 (0.0)	0
Soy milk	≥ 2	6 (4.1)	0	3 (6.2)	0	1 (2.4)	0	1 (2.8)	0	1 (5.6)	0

Values are number (percent); m = missing values; Freq. = frequency; Cells where 95% CI (not reported) do not overlap have been highlighted as significant; *Significantly greater than European, † Significantly greater than Polynesian; ‡ Significantly greater than Asian.

3.2.1.6 Treat foods

Overall, 77% and 32% of children consumed treat foods (biscuits, crisps, lollies, muesli bars and chocolate bars) at least one or two times per day respectively (Table 3.7). There were no differences among ethnic groups in the numbers of children consuming treat foods at least once or twice a day.

Biscuits, consumed by 72% of children at least twice a week were the most popular treat food for children, followed by crisps and lollies, which were consumed by 46% and 34% of children at least twice a week respectively. There were no differences among ethnic groups in the number of children consuming different types of treat foods.

Table 3.7 Number of children consuming total treat foods at least once or twice a day and varieties of treat foods at least twice a week by ethnicity, from an FFQ

Food / food group	**Freq.**	**Total (n = 147)**	**m**	**European (n = 48)**	**m**	**Polynesian (n = 31)**	**m**	**Indian (n = 36)**	**m**	**Asian (n = 18)**	**m**
All treat foods	**≥ 1 day**	**110 (77.5)**	**5**	**36 (78.3)**	**2**	**27 (69.2)**	**2**	**30 (83.3)**	**0**	**13 (72.2)**	**1**
All treat foods	**≥ 2 day**	**46 (32.4)**	**5**	**14 (30.4)**	**2**	**11 (28.2)**	**2**	**13 (36.1)**	**0**	**6 (35.3)**	**1**
Biscuits	≥ 2 week	105 (72.4)	2	37 (77.1)	0	27 (67.5)	1	26 (72.2)	0	12 (70.6)	1
Plain biscuits	≥ 2 week	100 (69.0)	2	35 (72.9)	0	26 (65.0)	1	25 (69.4)	0	11 (64.7)	1
Choc iced biscuits	≥ 2 week	29 (19.7)	0	8 (16.7)	0	8 (19.5)	0	8 (22.2)	0	4 (22.2)	0
Crisps	≥ 2 week	68 (46.3)	0	16 (33.3)	0	23 (56.1)	0	21 (58.3)	0	6 (33.3)	0
Lollies	≥ 2 week	50 (34.0)	2	11 (23.4)	1	16 (40.0)	0	14 (38.9)	0	8 (44.4)	0
Muesli bar	≥ 2 week	47 (32.0)	0	21 (43.8)	0	14 (34.1)	0	8 (22.2)	0	4 (22.2)	0
Chocolate bar	≥ 2 week	16 (11.0)	2	3 (6.4)	1	8 (20.0)	1	5 (13.9)	0	0 (0.0)	0

Values are number (percent); m = missing values; Freq. = frequency.

3.2.1.7 Sweet drinks

Overall 36% and 25% of children drunk sweet drinks (sugar sweetened drinks and juice) at least once and twice a day respectively (Table 3.8). There were no ethnic differences in the number of children consuming total sweet drinks at least once or twice a day, although the type of sweet drinks consumed was different between Indian and Polynesian children. Significantly more Indian than Polynesian children drunk juice at least twice a week, while significantly more Polynesian than Indian children consumed sugar sweetened drinks this often.

3.2.1.8 Takeaways and fries

Overall, 73% and 23% of children consumed takeaways or fries at least twice a week and five times a week respectively (Table 3.9). Significantly more Polynesian children than European children consumed takeaways or fries five times a week or more. There were no other ethnic differences in the number of children consuming takeaways or fries. The highest number of Polynesian children consumed takeaways at least twice a week, although the difference did not reach significance.

Table 3.8 Number of children consuming total sweet drinks at least once or twice a day and varieties of sweet drinks at least twice a week by ethnicity, from an FFQ

Food / food group	Freq.	Total (n = 147)	m	European (n = 48)	m	Polynesian (n = 41)	m	Indian (n = 36)	m	Asian (n = 18)	m
All sweet drinks	**≥ 1 day**	**53 (36.1)**	**0**	**17 (35.4)**	**0**	**18 (43.9)**	**0**	**10 (27.8)**	**0**	**4 (22.2)**	**0**
All sweet drinks	**≥ 2 day**	**39 (26.5)**	**0**	**13 (27.1)**	**0**	**15 (36.6)**	**0**	**6 (16.7)**	**0**	**3 (16.7)**	**0**
Juice	≥ 2 week	85 (57.8)	0	26 (54.2)	0	19 (46.3)	0	29 (80.6)*	0	8 (44.4)	0
Sugar sweetened drinks	≥ 2 week	51 (34.9)	1	14 (29.2)	0	22 (55.0)†	1	8 (22.2)	0	5 (27.8)	0

Values are number (percent); m = missing values; Freq. = frequency; Cells where 95% CI do not overlap have been highlighted as significant. * Significantly greater than Polynesian; † Significantly greater than Indian.

Table 3.9 Number of children consuming takeaways and fries at least two or five times a week by ethnicity, from an FFQ

Food / food group	Freq.	Total (n = 147)	m	European (n = 48)	m	Polynesian (n = 41)	m	Indian (n = 36)	m	Asian (n = 18)	m
All takeaways and fries	**≥ 2 week**	**104 (73.2)**	**5**	**31 (67.4)**	**2**	**32 (82.1)**	**2**	**24 (68.6)**	**1**	**13 (72.2)**	**0**
All takeaways and fries	**≥ 5 week**	**33 (23.2)**	**5**	**5 (10.9)**	**2**	**15 (38.5)***	**2**	**6 (17.1)**	**1**	**5 (27.8)**	**0**
Takeaways	≥ 2 week	75 (52.8)	5	24 (52.2)	2	27 (69.2)	2	14 (40.0)	1	8 (44.4)	0
Fries	≥ 2 week	22 (15.1)	1	7 (14.6)	0	6 (15.0)	1	3 (8.3)	0	3 (16.7)	0

Values are number (percent); m = missing values; Freq. = frequency; Cells where 95% CI do not overlap have been highlighted as significant; * Significantly greater than European.

3.2.2 Patterns of daily food consumption from the 24-hour food recall

3.2.2.1 Number of eating occasions

The average number of eating occasions per 24-hour period for children in the total sample was 6.8 ± 1.4.

Table 3.10 presents the average number of eating occasions per day by ethnicity. Asian and Indian children had on average 0.9 and 1.1 more eating occasions per 24-hour period respectively than European children (p = 0.02 and <0.01). Indian children had on average 0.6 more eating occassions per day than Polynesian children (p = 0.05).

Table 3.10 Number of eating occasions per 24-hour period by ethnicity, from a 24-hour food recall

	European (n = 48)	Polynesian (n = 41)	Indian (n = 36)	Asian (n = 18)	p-value
No. of eating occasions	6.2 ± 1.2	6.7 ± 1.6	7.4 ± 1.5*†	7.1 ± 1.2*	0.02

Values are number ± SD; No. = number; Cells where there is a significant difference have been highlighted;
* Significantly greater than European; † Significantly greater than Asian.

3.2.2.2 Foods consumed at meals and snacks

Table 3.11 presents the types of foods consumed at each meal, ranked by the number of children who reported consuming the food at least once at each meal on a 24-hour food recall. Only foods consumed by more than 10% of children are presented.

Cereal with milk was the most popular breakfast food, eaten by more than 70% of toddlers. Half this amount ate bread, and less than one quarter of children consumed fruit with breakfast. Fruit was the most popular morning and afternoon snack, followed by biscuits. Close to one half of children reported consuming bread for lunch, the next most popular items were meat; vegetables; fruit; and rice, noodles or pasta, which were all consumed by close to 40% of children. For dinner, the most popular foods were vegetables and meat, consumed by around three-quarters of children. The most popular carbohydrate food at dinner was rice, noodles or pasta, followed by potatoes. Around one in ten children consumed fish or lentils/beans for dinner during a typical day. Fruit was consumed by almost 40% of children at lunch, and 15% of children at dinner.

No one type of food was consumed by more than 10% of children as an evening snack (i.e. after dinner and before breakfast).

In addition to the foods presented in Table 3.11, 86% of children consumed milk at least once during a typical day, 33% consumed juice, 24% consumed sweetened milk, 16% consumed formula and 15% consumed sugar sweetened drink (numbers reported in Table 3.14).

Table 3.11 Foods consumed at each meal during a typical 24-hour period, from a 24-hour food recall

Meal	Food	Total (n = 147)
Breakfast	Cereal with milk	103 (70.1)
	Bread	52 (35.4)
	Fruit	34 (23.1)
Morning snack	Fruit	95 (64.6)
	Biscuits	33 (22.4)
	Crackers	27 (18.4)
	Cheese	18 (12.2)
	Bread	16 (10.9)
Lunch	Bread	69 (46.9)
	Meat	59 (40.1)
	Vegetables	59 (40.1)
	Fruit	58 (39.5)
	Rice, noodles or pasta	58 (39.5)
	Yoghurt	24 (16.3)
	Cheese	23 (15.6)
Afternoon snack	Fruit	86 (58.5)
	Biscuits	38 (25.9)
	Yoghurt	19 (12.9)
	Crackers	18 (12.5)
Dinner	Vegetables	112 (76.2)
	Meat	107 (72.8)
	Rice, noodles or pasta	84 (57.1)
	Potatoes	38 (25.9)
	Fruit	22 (15.0)

Values are number (percent); Only foods consumed by 10% or more of children in the total sample at each meal are reported.

Table 3.12 presents the types of foods consumed at each meal from the 24-hour recall, by ethnicity. Again, only foods consumed by more than 10% of children within each ethnic group are reported.

Cereal with milk was again the most popular breakfast food. Yoghurt was only consumed by European children, and eggs and rice, noodles or pasta were consumed by only Asian children at breakfast. Fruit was again the most popular morning and afternoon snack across all ethnic groups, followed by biscuits. More than one in ten Polynesian and Indian children consumed crisps as a morning snack.

Ethnic differences were evident in the foods children consumed at lunch. The most popular lunch food for European and Polynesian children was bread, and for Indian and Asian children rice, noodles or pasta. For dinner, meat was the most commonly consumed food for children from all ethnic groups except Indian. Around 80% of European, Polynesian and Asian children consumed meat for dinner during a typical day compared with only 50% of Indian children (for whom rice, noodles or pasta were the most popular dinner food). Other ethnic differences in the types of foods consumed at dinner were observed: lentils or beans and roti or chappati were only eaten by Indian children; potatoes only by European and Polynesian children; fish only by Polynesian children and eggs only by Asian children.

Table 3.12 Foods consumed at each meal during a typical 24-hour period by ethnicity, from a 24-hour food recall

	European (n=48)		Polynesian (n=41)		Indian (n=36)		Asian (n=18)	
Breakfast	Cereal with milk	35 (72.9)	Cereal with milk	35 (85.4)	Cereal with milk	24 (63.9)	Cereal with milk	7 (38.9)
	Fruit	17 (45.3)	Bread	16 (39.0)	Fruit	11 (30.6)	Bread	6 (33.3)
	Bread	21 (43.8)	Fruit	5 (12.2)	Bread	9 (25.0)	Egg	5 (27.8)
	Yoghurt	5 (10.4)					Rice, noodles or pasta	4 (22.2)
Morning snack	Fruit	34 (70.8)	Fruit	26 (63.4)	Fruit	21 (58.3)	Fruit	12 (66.7)
	Crackers	17 (35.4)	Biscuits	5 (12.2)	Biscuits	11 (30.6)	Biscuits	3 (16.7)
	Biscuits	12 (25.0)	Crisps	5 (12.2)	Crisps	4 (11.1)	Cheese	2 (11.1)
	Cheese	10 (20.8)	Crackers	5 (12.2)	Crackers	4 (11.1)		
	Bread	8 (16.7)						
Lunch	Bread	34 (70.8)	Bread	26 (63.4)	Rice, noodles, pasta	23 (63.9)	Rice, noodles or pasta	15 (83.3)
	Fruit	29 (60.4)	Meat	18 (43.9)	Vegetables	20 (55.6)	Vegetables	12 (66.7)
	Cheese	13 (27.1)	Fruit	16 (39.0)	Meat	15 (41.7)	Meat	9 (50.0)
	Meat	13 (27.1)	Vegetables	14 (34.1)	Fruit	10 (27.8)	Bread	3 (16.7)
	Rice, noodles, pasta	10 (20.8)	Rice, noodles, pasta	7 (17.1)	Yoghurt	8 (22.2)	Fruit	3 (16.7)
	Vegetables	10 (20.8)	Yoghurt	7 (17.1)	Bread	7 (16.7)	Fish	2 (11.1)
	Yoghurt	8 (16.7)	Cheese	6 (14.6)	Lentils and beans	6 (16.7)	Egg	2 (11.1)
					Roti or chappati	5 (13.9)		
Afternoon snack	Fruit	33 (68.8)	Fruit	24 (58.5)	Fruit	12 (33.3)	Fruit	14 (77.8)
	Biscuits	12 (25.0)	Biscuits	7 (17.1)	Biscuits	11 (30.6)	Biscuits	7 (38.9)
	Crackers	11 (22.9)	Yoghurt	7 (17.1)	Yoghurt	7 (16.7)	Yoghurt	3 (16.7)
	Cheese	7 (14.6)	Bread	7 (17.1)	Bread	5 (13.9)	Cheese	3 (16.7)
							Bread	2 (11.1)
Dinner	Meat	38 (79.2)	Meat	33 (80.5)	Rice, noodles, pasta	27 (75.0)	Meat	15 (83.3)
	Vegetables	38 (79.2)	Vegetables	32 (78.0)	Vegetables	26 (72.2)	Rice, noodles or pasta	15 (83.3)
	Rice, noodles or pasta	21 (43.8)	Rice, noodles, pasta	18 (43.9)	Meat	18 (50.0)	Vegetables	14 (77.8)
	Potatoes	18 (37.5)	Potatoes	17 (41.5)	Lentils or beans	12 (33.3)	Egg	2 (11.1)
	Fruit	11 (22.9)	Fish	8 (19.5)	Roti or chappati	10 (27.8)	Fruit	2 (11.1)
	Yoghurt	10 (20.8)			Fruit	5 (13.9)	Icecream	2 (11.1)
	Icecream	6 (12.5)						

Values are number (percent); only foods consumed by 10% or more of children within each ethnic group are reported.

Table 3.13 presents drinks consumed at least once during a typical day from the 24-hour recall, by ethnicity. Only drinks consumed by more than 10% of children within each ethnic group are presented.

Milk (which excluded milk served with cereal) was the most popular drink among all ethnic groups. Sweetened milk was a popular beverage for Indian and Asian children, consumed by more than one-third of children in these ethnic groups, and formula a popular beverage for Asian children, consumed by just under half of children in this ethnic group, during a typical day. Sugar sweetened drinks were only consumed by more than one in ten European and Polynesian children during a typical day, and breast milk only by Polynesian and Indian children.

Table 3.13 Drinks consumed at least once during a typical 24-hour period by ethnicity, from a 24-hour food recall.

European (n = 48)		Polynesian (n = 41)		Indian (n = 36)		Asian (n = 18)	
Milk	42 (87.5)	Milk	37 (90.2)	Milk	30 (83.3)	Milk	14 (77.8)
Juice	14 (29.2)	Sweetened milk	16 (39.0)	Juice	16 (44.4)	Formula	8 (44.4)
Sugar sweetened drinks	8 (16.7)	Juice	13 (31.7)	Sweetened milk	13 (36.1)	Juice	3 (16.7)
Formula	7 (14.6)	Sugar sweetened drinks	10 (24.4)	Formula	5 (13.9)	Sweetened milk	2 (11.1)
Sweetened milk	5 (10.4)	Breast milk	5 (12.2)	Breast milk	4 (11.1)		

Values are number (percent); only foods consumed by 10% or more of children within each ethnic group are reported

3.2.3 Validation of the FFQ with the 24-hour food recall

As a means of validation, the FFQ was compared with the 24-hour food recall. Table 3.14 presents foods ranked in order of the number of children who consumed them at least once during a typical day from the 24-hour food recall, and foods ranked in order of the number of children who consumed them at least twice a week from the FFQ. To allow for comparison with the 24-hour food recall, some FFQ food items have been combined (see Appendices 5 for a list of FFQ food items and corresponding 24-hour recall foods). Foods which were not included in the FFQ but were recorded by the child's parents on the 24-hour food recall included crackers, ice-cream, muffins, nuts, ice blocks, jelly and chicken nuggets.

The top ten most commonly consumed foods were the same between both methods, with the exception of crackers, which was ranked the tenth most commonly consumed food from the 24-hour food recall, but not included on the FFQ. Foods which were more than four rankings apart included formula (16th on the 24-hour food recall, 22nd on the FFQ), muesli bars (22nd versus 18th) and lollies (23rd versus 17th)

Table 3.14 Foods ranked by the number of children who reported consumption at least once on a 24-hour recall and at least twice a week on a FFQ

	24-hour food recall (n = 147)	Rank* 24-hour food recall, FFQ	FFQ (n = 147)	m
Fruit	140 (95.2)	1, 1	142 (99.3)	4
Vegetables	126 (85.7)	2, 2	138 (97.9)	6
Milk	126 (85.7)	3, 6	132 (89.8)	0
Meat	121 (82.3)	4, 5	130 (90.9)	4
Bread	110 (74.8)	5, 4	137 (93.8)	1
Cereal	105 (71.4)	6, 7	122 (83.0)	0
Rice, noodles or pasta	101 (68.7)	7, 3	140 (95.9)	1
Biscuits	68 (46.3)	8, 9	105 (72.4)	2
Yoghurt	58 (39.5)	9, 8	112 (78.3)	4
Crackers	50 (34.0)		N/A	N/A
Cheese	49 (33.3)	10, 10	100 (68.5)	1
Juice	49 (33.3)	11, 11	85 (57.8)	0
Potatoes	45 (30.6)	12, 13	71 (48.6)	1
Sweetened milk	36 (24.5)	13, 15	61 (41.5)	0
Crisps	27 (18.4)	14, 14	68 (46.3)	0
Egg	26 (17.7)	15, 12	73 (50.3)	2
Formula	23 (15.6)	16, 22	27 (18.5)	1
Sugar sweetened drinks	22 (15.0)	17, 16	51 (34.7)	1
Lentils and beans	20 (13.6)	18, 19	45 (31.2)	3
Fish	19 (12.9)	19, 20	30 (20.5)	1
Roti or chappati	16 (10.9)	20, 21	30 (20.4)	1
Ice-cream	14 (9.5)		N/A	N/A
Breast milk	11 (7.5)	21, 24	12 (8.2)	0
Muesli bar	7 (4.8)	22, 18	47 (32.0)	0
Muffins	7 (4.8)		N/A	N/A
Nuts	7 (4.8)		N/A	N/A
Ice block	6 (4.1)		N/A	N/A
Lollies	5 (3.4)	23, 17	50 (34.5)	2
Jelly	5 (3.4)		N/A	N/A
Fish fingers	5 (3.4)	24, 23	14 (9.5)	0
Chicken nuggets	5 (3.4)		N/A	N/A

Values are number (percent); FFQ = food frequency questionnaire; m = missing values; N/A = not applicable - food item was not included on the FFQ; * foods are ranked by the number of children who reported consuming them at least once on the 24-hour food recall, and at least twice a week on the FFQ.

3.2.4 Patterns of daily activity from the 24-hour activity recall

3.2.4.1 Time spent in different activities

Table 3.15 presents the average hours children spent in each of six activities per 24-hour period from the 24-hour recall. In the total sample, children slept for an average of 12.5 hours per night, were involved in active play for almost 5 hours a day, quiet play for almost 3 hours, spent almost 2.5 hour sitting, and 1 hour watching TV.

Table 3.15 Average hours spent in different activities per 24-hour period, from a 24-hour activity recall

Activity	Hours (n = 147)
Sleeping	12.5 ± 1.1
Active play	4.8 ± 2.2
Quiet play	2.9 ± 1.9
Sitting	2.3 ± 0.9
Watching TV	1.0 ± 0.8
Other	0.4 ± 0.4

Values are mean ± SD; TV = television.

Table 3.16 presents the average hours children spent in each activity per 24-hour period by ethnicity. European children slept an average of 13.1 hours per 24 hour period, significantly longer than Polynesian by 0.9 hours ($p = <0.01$), Indian by 1.0 hour ($p = <0.01$) and Asian by 0.8 hours ($p = <0.01$). European children watched TV on average 0.8 hours per day, significantly less than Polynesian by 0.4 hours ($p = 0.03$), Indian by 0.4 hours ($p = 0.02$) and Asian by 0.5 hours ($p = 0.01$). European children also spent on average 2.6 hours in quiet play, significantly less than Indian children by 0.9 hours ($p = 0.04$).

Table 3.16 Average hours spent in different activities per 24-hour period by ethnicity, from a 24 -hour activity recall

	European (n = 48)	Polynesian (n = 41)	Indian (n = 36)	Asian (n = 18)	p-value
Sleeping	13.1 ± 1.0*†‡	12.2 ± 1.2	12.1 ± 1.0	12.3 ± 0.8	p = <0.01
Active play	4.6 ± 2.0	4.9 ± 2.3	4.7 ± 2.2	5.3 ± 2.6	p = 0.78
Quiet play	2.6 ± 1.6	3.1 ± 2.3	3.5 ± 1.8§	2.4 ± 2.0	p = 0.20
Sitting	2.5 ± 0.9	2.3 ± 0.9	2.1 ± 0.8	2.1 ± 1.0	p = 0.38
Watching TV	0.8 ± 0.7	1.1 ± 0.8§	1.2 ± 0.8§	1.3 ± 0.8§	p = 0.05
Other	0.4 ± 0.4	0.3 ± 0.4	0.4 ± 0.4	0.5 ± 0.6	p = 0.43

Values are mean ± SD; TV = television; Cells where there is a significant difference have been highlighted;
* Significantly greater than Polynesian, † Significantly greater than Indian, ‡ Significantly greater than Asian, § Significantly greater than European.

Table 3.17 presents the number of children sleeping for 12 or more hours by ethnicity. Significantly more European children slept for more than 12 hours per 24-hour period than any other ethnic group. The least amount of Indian, followed by Polynesian children slept for 12 hours per 24-hour period.

Table 3.17 Number of children sleeping 12 hours or more per 24-hour period by ethnicity, from a 24-hour activity recall

	European (n = 48)	Polynesian (n = 41)	Indian (n = 36)	Asian (n = 18)
Sleeping 12 hours or more	39 (81.2) *†‡	19 (46.3)	14 (38.9)	11 (61.1)

Values are number (percent). Cells where 95% CI intervals do not overlap have highlighted as significant;
* Significantly greater than Polynesian; † Significantly greater than Indian; ‡ Significantly greater than Asian

3.2.4.2 Time awake and time asleep

The average wake up time for the total sample was 7:19 am ± 63 minutes, and the average time to sleep for the total sample was 8:19pm ± 69 minutes.

Table 3.18 presents the average time children woke up in the morning and went to sleep at night by ethnicity. European children woke up in the morning at 6:50 am, significantly earlier than Polynesian (p = <0.01), Indian (p = 0.01) and Asian (p = 0.01) children. European children went to bed at around 7:30 pm, significantly earlier than Polynesian, Indian and Asian children (p = <0.01).

Table 3.18 Time awake in the morning and time asleep at night from a 24-hour recall, by ethnicity

	European (n = 48)	Polynesian (n = 41)	Indian (n = 36)	Asian (n = 18)	p-value
Time awake (am)	6:50am ± 40 min	7:37am ± 77 min*	7:35am ± 62 min*	7:31am ± 47 min*	<0.01
Time asleep (pm)	7:32 pm ± 47 min	9:02 pm ± 61 min*	8:57 pm ± 58 min*	8:53 ± 58 min*	<0.01

Values are mean ± SD; Min = minutes. Cells where a significant difference exists have been highlighted.
* Significantly later than European.

3.3 Section B: Body composition

In this section height, weight and BMI measurements; height, weight, and BMI z-scores; and FM, FFM and %BF are presented. Results are presented first for the overall sample, then by sex and ethnicity.

3.3.1 Height, weight and BMI

The average height of children in the total sample was 89.5 ± 4.5 cm, the average weight of children was 13.7 ± 2.0 kg and the average BMI of children was 17.0 ± 1.7 kg/m^2.

Table 3.19 Height, weight and BMI by sex

	Girls (n = 78)	**Boys (n = 66)**	**p-value****
Height (cm)	89.0 ± 4.6	90.1 ± 4.3	0.44
Weight (kg)	13.5 ± 2.1	13.9 ± 2.0	0.50
BMI (kg/m^2)	17.0 ± 1.7	17.1 ± 1.8	0.77

Values are unadjusted mean ± SD; cm = centimeters; kg = kilograms; BMI = body mass index; ** p-value adjusted for age.

Table 3.19 presents unadjusted height, weight and BMI measurements by sex. After adjustment for age, there were no significant differences in height, weight or BMI between boys and girls.

Table 3.20 Height, weight and BMI by ethnicity

	European (n = 48)	Polynesian (n = 41)	Indian (n = 35)	Asian (n = 18)	Other (n = 4)	P-value**
Height (cm)	88.7 ± 4.5	91.5 ± 4.4*†‡	88.9 ± 4.2	88.1 ± 4.1	91.3 ± 3.7	p = <0.05
Weight (kg)	13.5 ± 1.9	14.9 ± 2.1*†‡	12.7 ± 1.9	13.2 ± 1.4	13.6 ± 1.0	p = <0.01
BMI (kg/m²)	17.1 ± 1.6†	17.7 ± 1.7†	16.1 ± 1.9	17.0 ± 1.5	16.3 ± 0.5	p = <0.01

Values are unadjusted mean ± SD. BMI = body mass index, kg = kilograms, cm = centimeters; ** p-value adjusted for age; Cells where a significant difference exists have been highlighted; * Significantly greater than European adjusted for age, † Significantly greater than Indian adjusted for age; ‡ Significantly greater than Asian adjusted for age.

Table 3.20 presents unadjusted height, weight and BMI measurements by ethnicity. After adjustment for age, the following differences reached statistical significance:

- Polynesian children were 2.0 cm taller than European (p = <0.05), 2.7 cm taller than Indian (p = <0.01) and 2.9 cm taller than Asian children (p = <0.01),
- Polynesian children were 1.2 kg heavier than European (p = <0.01), 2.1 kg heavier than Indian (p = <0.001) and 1.6 kg heavier than Asian children (p = <0.01),
- Polynesian children had a BMI 1.5 kg/m² higher than Indian children (p = <0.01), and European children had a BMI 0.9 kg/m² than Indian children (p = 0.05).

Table 3.21 Children classified as thin, normal, overweight and obese based on international BMI cut-off points

BMI classification*	(n = 146)
Thin	15 (10.2)
Normal	92 (62.6)
Overweight	20 (20.4)
Obese	9 (6.1)

Values are number (percent); *based on international BMI cut-off points (Cole et al., 2007).

Table 3.21 presents children classified as thin, normal , overweight and obese, based on international BMI cut-off points by Cole et al (2007). One in ten children in the total sample was thin, one in five overweight, and just over one in twenty obese (Table 3.31). A similar percentage of boys and girls were classified as thin, normal, overweight and obese.

Table 3.22 Children in each ethnic group classified as thin, normal, overweight and obese based on international BMI cut-off points

BMI classification*	European (n = 48)	Polynesian (n = 41)	Indian (n = 35)	Asian (n = 18)	Other (n = 4)
Thin	3 (6.3)	3 (7.3)	9 (25.0)	0 (0.0)	0 (0.0)
Normal	33 (68.8)	20 (48.8)	20 (55.6)	15 (83.3)†	4 (100.0)
Overweight	10 (20.8)	13 (31.7)	5 (13.9)	2 (11.1)	0 (0.0)
Obese	2 (4.2)	5 (12.2)	1 (2.8)	1 (5.6)	0 (0.0)

Values are number (percent); *based on international BMI cut-off points (Cole et al., 2007); Cells where a significant difference exists have been highlighted; † significantly greater than Polynesian.

Table 3.22 present children classified as thin, normal, overweight and obese within each ethnic group. Significantly more Asian children than Polynesian children were classified as normal. Although other differences between ethnic groups did not reach statistical significance, the highest prevalence of thin was observed in the Indian ethnic group, and the highest prevalence of overweight and obesity observed in the Polynesian group.

3.3.2 Height, weight, and BMI z-scores

The height-for-age z-score for the total sample was 0.02 ± 1.19, the weight-for-age z-score was 0.63 ± 1.15 and the BMI-for-age z-score was 0.88 ± 1.15.

Table 3.23 Height-, weight- and BMI-for-age z-scores by sex

Z-score*	Girls (n = 78)	Boys (n = 66)	p- value
Height-for-age	0.13 ± 1.11	- 0.10 ± 1.15	0.24
Weight-for-age	0.73 ± 1.12	0.52 ± 1.18	0.27
BMI-for-age	0.93 ± 1.11	0.82 ± 1.28	0.58

Values are mean ± SD; BMI = body mass index; * z-score based on World Health Organisation 2006 growth standards.

Table 3.23 presents height-for-age, weight-for-age and BMI-for-age z-scores by sex. There were no significant differences in z-scores between boys and girls, although girls tended to have slightly higher height, weight and BMI-for-age z-scores than boys.

Table 3.24 Height-, weight- and BMI-for-age z-scores by ethnicity

Z-score*	European (n = 48)	Polynesian (n = 41)	Indian (n = 36)	Asian (n = 18)	Other (n = 4)	p-value
Height	-0.06 ± 1.20	0.50 ± 1.18*†‡	-0.31 ± 1.07	-0.27 ± 1.26	0.59 ± 0.18	0.02
Weight-	0.63 ± 1.03	1.26 ± 1.12*†‡	0.01 ± 1.14	0.45 ± 1.00	0.39 ± 0.23	<0.01
BMI	0.94 ± 1.11†	1.38 ± 1.10†	0.26 ± 1.30	0.86 ± 0.97	0.47 ± 0.32	<0.01

Values are mean ± SD; BMI = body mass index, kg/m²; * z-scores for age based on World Health Organisation 2006 growth standards; Cells where there is a significant difference have been highlighted; * Significantly greater than European; † Significantly greater than Indian; ‡ Significantly greater than Asian

Table 3.24 presents height, weight and BMI-for-age z-scores by ethnicity. The following differences in z-scores between ethnic groups were significant (illustrated in Figures 1.4 to 1.6):

- Polynesian children had **height-for-age** z-scores that were 0.57 SD higher than European (p = 0.02), 0.81 SD higher than Indian (p = <0.01) and 0.77 SD higher than Asian (p = 0.02) children.

- Polynesian children had **weight-for-age** z-scores that were 0.63 SD higher than European (p = 0.08), 1.25 SD higher than Indian (p = <0.001), and 0.81 SD higher than Asian (p = 0.06) children.
- Polynesian children had **BMI-for-age** z-scores that were 1.12 SD higher than Indian children (p = <0.01).
- European children had **weight-for-age** z-scores that were 0.62 SD higher (p=0.01) than Indian children.
- European children had **BMI-for-age** z-scores that were 0.69 SD higher than Indian children (p = <0.01).

3.3.3 Fat mass, fat free mass, and percentage body fat

In the total sample, mean FFM was 11.1 ± 1.3 kg, mean FM was 2.6 ± 0.6 kg and mean %BF was 18.7 ± 4.5%.

Table 3.25 FFM, FM and %BF by sex

	Girls (n = 78)	**Boys (n = 66)**	**P value**
FFM (kg)	10.8 ± 1.3	11.5 ± 1.3*	p = <0.01**
FM (kg)	2.8 ± 0.9†	2.4 ± 0.9	p = <0.01**
%BF (%)	20.1 ± 4.1‡	17.0 ± 4.5	p = <0.01

Values are unadjusted mean ± standard deviation; FFM = fat free mass; FM = fat mass; %BF = percent body fat; ** p-value adjusted for height and weight; *Significantly greater than girls, adjusted for height and weight, † significantly greater than boys, adjusted for height and weight. ‡ Significantly greater than boys.

Table 3.25 presents the unadjusted mean FFM and FM for boys and girls. Girls had on average 3.1% more body fat than boys. After adjusting for height and weight, the average FFM of boys was 0.5 kg higher than that of girls and the average FM of girls was 0.5 kg higher than that of boys.

Table 3.26 FFM, FM and %BF by sex and ethnicity

	European	Polynesian	Indian	Asian	Other	p-value
Girls						
n	26	22	15	12	3	
FFM (kg)	10.5 ± 0.9 *	11.8 ± 1.5 *†	9.9 ± 1.1	10.4 ± 0.8	11.0 ± 1.1	p = <0.01**
FM (kg)	2.6 ± 1.0	3.2 ± 1.0	2.6 ± 0.6 ‡§	2.7 ± 0.7 §	2.4 ± 0.5	p = <0.01**
%BF (%)	19.0 ± 4.9	21.0 ± 3.8	20.1 ± 3.2	20.6 ± 3.2	18.2 ± 3.9	p = 0.37
Boys						
n	22	18	19	6	1	
FFM (kg)	11.5 ± 1.4 *	12.2 ± 1.0 *	10.9 ± 1.3	11.0 ± 1.1	11.5	p = 0.10**
FM (kg)	2.4 ± 0.9	2.8 ± 0.8	2.2 ± 1.0 ‡§	2.1 ± 0.8	2.6	p = 0.10**
%BF (%)	17.0 ± 4.3	18.5 ± 4.1	16.1 ± 5.1	15.4 ± 4.2	18.4	p = 0.42
Total						
n	48	40	34	18	4	
FFM (kg)	11.0 ± 1.2*	12.0 ± 1.3*	10.5 ± 1.3	10.6 ± 0.9	11.1 ± 0.9	p = <0.05**
FM (kg)	2.5 ± 0.9	3.0 ± 0.9	2.4 ± 0.9‡§	2.5 ± 0.9	2.5 ± 0.4	p = <0.05**
%BF (%)	18.0 ± 4.7	19.9 ± 4.1	18.1 ± 4.9	18.9 ± 4.3	18.2 ± 3.2	p = 0.31

Values are unadjusted mean ± standard deviation; FFM = fat free mass, FM = fat mass; %BF = percent body fat; ** p-value adjusted for height, weight and age; Cells where a significant difference exists have been highlighted; * Significantly greater than Indian, adjusted for height, weight and age; †Significantly greater than Asian, adjusted for height, weight and age; ‡ Significantly greater than European adjusted for height, weight and age; § Significantly greater than Polynesian adjusted for height, weight and age.

Table 3.26 presents the unadjusted FFM, FM and %BF of children by sex and ethnicity. After adjusting for age only, Polynesian toddlers had 2% more body fat than European toddlers (p = 0.04). After adjusting for age, weight and height, the following differences in FFM and FM reached statistical significance (illustrated in Figures 3.1 and 3.2):

Among girls:

- The average **FFM** of Polynesian girls was 0.5 kg higher than Indian (p = <0.001) and 0.3 kg higher than Asian girls (p = <0.05),
- The average **FM** of Indian girls was 0.4 kg higher than European girls (p = 0.001), and 0.5 kg higher than Polynesian girls (p = <0.001).

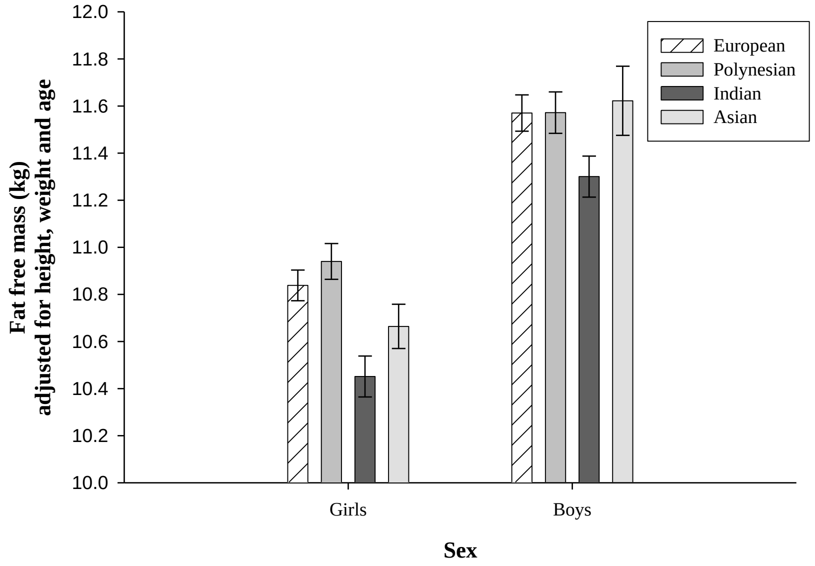
Among boys:

- The average **FFM** of Polynesian boys was 0.3 kg higher (p = <0.05), and the average **FFM** of European boys was 0.3 kg higher (p = <0.05), than Indian boys.
- The average **FM** of Indian boys was 0.3 kg higher than European boys (p = <0.05) and 0.3 kg higher than Polynesian boys (p = <0.05).

Among the total sample:

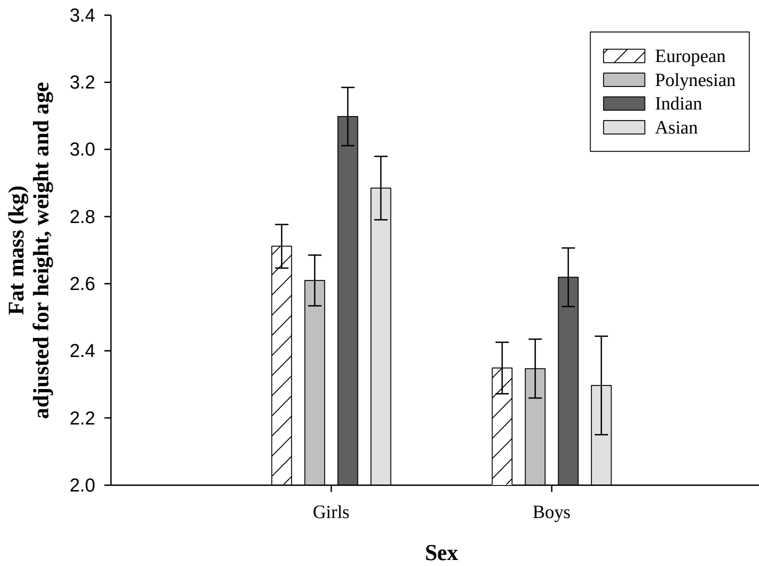
- The average **FFM** of European children was 0.3 kg higher than Indian children (p = <0.01)
- The average **FFM** of Polynesian children was 0.3 kg higher than Indian children (p=0.01)
- The average **FM** of Indian children was 0.3 kg higher than European children (p=<0.01) and Polynesian children (p=0.01).

Figure 3.1 FFM by sex and ethnicity adjusted for height, weight and age



Error bars = standard error; FFM = fat free mass; kg = kilograms. ‘Other’ ethnic group not presented due to small sample size.

Figure 3.2 FM by sex and ethnicity adjusted for height, weight and age.



Error bars = standard error; FM = fat mass; kg = kilograms. ‘Other’ ethnic group not presented due to small sample size.

3.4 Section C: Associations among food and activity patterns, body composition, maternal GDM treatment and maternal glucose control.

3.4.1 Associations between food and activity patterns and body composition

No associations between food and activity patterns (consumption of food groups and individual foods, and time spent in different activities) and body composition (%BF and FM adjusted for height, weight and age) were identified. Specifically, no associations between the consumption of treat foods, sweet drinks and takeaways and fries and %BF and FM adjusted for height, weight and age were identified.

3.4.2 Associations between maternal GDM treatment, maternal glucose control and food and activity patterns

No associations between maternal GDM treatment (metformin versus insulin) and maternal glucose control (tertile one, two or three) and food and activity patterns (consumption of food groups and individual foods, and time spent in different activities) were identified.

CHAPTER 4: DISCUSSION

This body of work is an examination of food and activity patterns and body composition in a cohort of 2 year old boys and girls representing four principal ethnic groups in NZ. Furthermore, because the mother's of these children were treated for GDM, effects of maternal treatment and glucose control with these patterns of behavior were analysed. This is the first time that this combination of factors has been explored. Initially the key findings are summarized and then discussed in depth in the context of current literature, limitations acknowledged and strengths highlighted, conclusions drawn and recommendations made.

4.1 Summary of main findings

Presented below is a summary of the main findings of this study.

Section A: Food and activity patterns

Patterns of food and food group consumption

- Overall, 64% of children did not consume breads and cereals at least four times day, 34% did not consume fruit at least twice a day and 24% did not consume vegetables twice a day.
- Significantly less Indian than European children consumed fruit at least twice a day, and meat at least once day.
- Overall, 77% and 36% of children consumed treat foods and sweet drinks at least once a day respectively, and 73% of children consumed takeaways or fries at least twice a week.
- Significantly more Polynesian than European children consumed takeaways or fries five times a week or more.
- A number of differences among ethnic groups in the consumption of individual foods were identified, for example, significantly more Asian than European children consumed rice at least twice a week, while significantly more European children than Asian children consumed cereal this often.

Patterns of daily food consumption

- Asian and Indian children had on average one more eating occasion per 24-hour period than European children.
- Overall, cereal with milk was the most popular breakfast food; bread the most popular lunch food; and meat the most popular dinner food. Fruit and biscuits were popular snack foods during a typical day and milk and juice popular drinks.
- The types of foods children consumed at meals were different among ethnic groups, for example, bread was the most popular lunch food for European and Polynesian children, while rice, noodles and pasta the most popular lunch food for Indian and Asian children. .

Patterns of daily activity

- Children slept for around 12.5 hours a night, watched 1 hour of TV and were engaged in active play for almost 5 hours a day.
- European children slept for 1 hour longer and watched around 0.5 hours less TV each day than other ethnic groups.
- European children woke up just over half an hour earlier in the morning than other ethnic groups, and went to sleep around one and a half hours earlier at night.

Section B: Body composition

Height, weight and BMI

- Based on international BMI cut-off points, one in ten children in the total sample was thin, one in five overweight, and just over one in twenty obese.
- Height, weight and BMI were not different between boys and girls.
- Polynesian children were taller and heavier than other ethnic groups and Polynesian and European children had higher BMI values than Indian children.

Height-, weight- and BMI-for-age z-scores

- Polynesian children had higher height- and weight-for-age z-scores than other ethnic groups.
- Polynesian and European children had higher BMI-for-age z-scores than Indian children.

FM, FFM and %BF

- Girls had on average 3% more body fat than boys, and adjusted for height and weight, girls had 0.5kg more FM than boys.
- Polynesian children had 2% more body fat than European children.
- Adjusted for height, weight and age Indian children had 0.3 kg more FM than European and Polynesian children.

Section C: Associations between variables

- No associations between food and activity patterns and body composition were found.
- No associations between maternal glucose control, GDM treatment and food and activity patterns were found.

4.2 Section A: Food and activity patterns

Research has identified a number of food and activity patterns associated with childhood obesity. Most research has, however, been conducted in adults and school-aged children (as well as breast-feeding in infants), with limited research involving young children. As food and activity patterns that develop in early childhood may persist into later years, the preschool period has been identified as an ideal time for interventions aimed at preventing obesity throughout the life course (Reilly, 2008).

Differences in food and activity patterns among ethnic groups may explain at least some of the ethnic disparity in the prevalence of obesity, CVD and T2DM. Although genetic and epigenetic factors will also play a role, identifying food and activity patterns prevalent in ethnic groups with higher rates of obesity could indicate these patterns are associated with increased obesity risk (Kumanyika, 2008).

For public health recommendations to be made, an understanding of the food and activity patterns of toddlers and preschool children in NZ are needed. Additionally, ethnic differences in food and activity patterns need to be identified, so that interventions can be tailored for at risk groups. This section will summarise and discuss the major findings from this study regarding food and activity patterns in NZ toddlers and differences among ethnic groups.

4.2.1 Patterns of food and food group consumption.

4.2.1.1 ***Fruit and vegetables***

Fruit and vegetables are an important source of vitamins, minerals and fibre for children and consumption in adulthood is associated with a reduced risk of chronic diseases such as CVD and cancer (van't Veer et al., 2000). As fruit and vegetable intake in childhood appears to track into adolescence (Kelder et al., 1994; Resnicow et al., 1998; Lytle et al., 2000), patterns of fruit and vegetable consumption that develop in early childhood could have long-ranging effects on health.

Similar to the ABC study of NZ European 3.5 year olds (Theodore et al., 2006), and the CNS pilot study of NZ European, Maori and Pacific 1 to 4 year olds (Ministry of Health, 2001), one in three toddlers in this study did not consume fruit at least twice a day, and one in four did not consume vegetables twice day. Fruit consumption has been shown to decline with age (Munoz et al., 1997), and consistent with this observation, a higher proportion of 2 year old children in this study consumed fruit twice a day than older children in the 2002 CNS (Ministry of Health, 2003).

Significantly less Indian than European children consumed fruit at least twice a day, and less Indian than European children consumed vegetables this often, although the difference did not reach statistical significance. Similarly, in a UK study of British South Asian and white children aged 8 to 11 years, South Asian children were found to consume less fresh fruit and vegetables than white children (Whincup et al., 2002). The authors concluded the low consumption of fruit and vegetables could be partly responsible for the higher prevalence of insulin resistance observed among South Asian children in this study.

The varieties of fruit and vegetables children consumed in this study were not examined (beyond for example ‘fresh fruit’ and ‘dried fruit’), and differences between ethnic groups were therefore limited. Significantly more Polynesian than Asian children consumed potatoes at least twice a week and taro, a common Pacific staple in NZ (Ministry of Health, 2003), was consumed exclusively by Polynesian children. The consumption of traditional varieties of fruit and vegetables has been observed in other studies of NZ children – for example Chinese herbs and bok choy were popular in a study of Asian children (Soh et al., 2000), and taro, cassava and green bananas in a study of Pacific children (Rush et al., 2008a).

The results of this study may overestimate the proportion of children meeting the MoH guidelines for fruit and vegetable intake, as respondents tend to overestimate fruit and vegetable intake in questionnaires (Bingham et al., 1994). Furthermore, servings sizes were not examined in this study, and the results of the ABC study suggest young children may not consume whole servings of vegetables (Theodore et al., 2006). This is especially worrying for Indian children, where a significant proportion of children already do not meet the MoH guidelines.

4.2.1.2 ***Breads and cereals***

Breads and cereals (including rice, noodles, pasta, roti, chappati, naan and dumplings) are an important source of carbohydrate, fibre, folate and iron in NZ children's diets (Soh et al., 2002; Ministry of Health, 2003; Wall et al., 2009) and consumption appears to be protective against obesity (Newby, 2009). Of concern, almost two-thirds of toddlers in this study did not consume breads and cereal at least four times a day as recommended by the MoH, consistent with high proportion of preschoolers in the ABC study who did not consume breads and cereals this often (90%) (Theodore et al., 2006). Carbohydrate based 'treat' foods, such as biscuits, were not included in the breads and cereals food group in this or the ABC study, but were commonly consumed by children in both studies. The high proportion of children not consuming breads and cereals four or more times a day could reflect the popularity of foods other than breads and cereals as between meal snacks (discussed later in this chapter).

Bread, breakfast cereal and rice were the three most commonly consumed foods from the breads and cereals group. Although wholegrain breads and cereals supply more fibre and nutrients than refined breads and cereals, (Slavin et al., 2000), and appear to be protective against obesity (Albertson et al., 2009) white bread and white rice were more popular among NZ children in this and other studies (Ministry of Health, 2001; Ministry of Health, 2003; Rush et al., 2008a). Consistent with the 2002 CNS, (Ministry of Health, 2003) significantly more European children in this study consumed grainy brown bread at least twice a week than Polynesian children; and although the difference did not reach significance, more Polynesian than European children consumed white bread this often.

As mentioned previously, dietary fibre may be of particular importance to young children, who tend to be at risk of constipation (Williams, 1995). The high percentage of toddlers in this study not meeting the MoH recommended servings of foods such as fruit, vegetables, and breads and cereals (the main sources of dietary fibre for older children in the 2002 CNS (Ministry of Health, 2003)), combined with the relatively low percentage of children consuming wholegrain breads and cereals, could suggest some children are at risk of inadequate fibre intakes. Overseas studies have found a high proportion of toddlers and preschoolers have inadequate fibre intakes (Devaney et al., 2004; Kranz, 2006).

Breakfast cereal was a popular food for children in this and other studies of NZ preschoolers (Ministry of Health, 2001; Theodore et al., 2006). Breakfast cereal consumption is associated with overall improved diet quality, including higher micronutrient and lower fat intakes (Gibson et al., 1995; Barton et al., 2005). Non-sugary breakfast cereal was more popular among children in this study than sugary breakfast cereal, similar to the CNS pilot study where the most popular breakfast cereals were Weet-Bix, rice bubbles and cornflakes (Ministry of Health, 2001). Although breakfast cereal is a popular food for young children, like fruit and vegetables, its consumption appears to decline with age (Ministry of Health, 2003). The number of toddlers in this study who consumed breakfast cereal at least *twice* a week was almost double the number of school-aged children in the 2002 CNS who consumed breakfast cereal at least *once* a week (Ministry of Health, 2003).

Ethnic differences were observed in types of breads and cereals toddlers in this study consumed – for example significantly more European children consumed breakfast cereal than Asian children, while significantly more Asian children consumed rice than European children. Roti and chappati were consumed almost exclusively by Indian children. These differences highlight the need for nutrition messages to be tailored for different populations, taking into account the types of foods commonly consumed by children within in ethnic group.

*4.2.1.3 **Meat and other protein***

The protein intake of children in developed countries is generally adequate, and more than nine out of ten toddlers in this study consumed meat or other protein (eggs, lentils and beans) at least once a day, as recommended by the MoH. Other meat (meat other than red meat, for example chicken and pork) and red meat were the most popular meats consumed. Chicken was the most commonly consumed meat in other studies of NZ children (Ministry of Health, 2001; Ministry of Health, 2003; Theodore et al., 2006; Rush et al., 2008a).

Less than half of Indian toddlers in this study consumed meat (not including eggs, lentils or beans) at least once a day, significantly less than the number of European and Polynesian toddlers consuming meat this often. Low meat consumption is common in India due to vegetarianism and scarcity of meat for consumption (Antony, 2003), however Indian migrant populations may also consume relatively little meat. In a study of 1700, 15 month old South Asian children in the UK (Lawson et al., 1998), daily meat consumption was reported in 21% of Indian, 30% of Pakistani, and 53% of Bangladeshi children compared with 69% of white children. Although adequate protein and energy can be obtained from plant based diets, children who consume little or no meat are at risk micronutrient deficiencies, such as low iron and vitamin B_{12}.

The consumption of meat (and fruit) appears to be important for adequate iron status in young children (Karr et al., 1996; Mira et al., 1996; Thane et al., 2000). Iron deficiency is common among migrant Indian children in the UK (Lawson et al., 1998), and in a study of NZ infants aged 6 to 23 months, the prevalence of iron deficiency was highest in the 'Other' ethnic group - which included South-East Asian, Chinese and Indian children (Grant et al., 2007b). The authors concluded that cultural practices may increase the risk of iron deficiency among children and that their results warranted further investigation. The study here has demonstrated low levels of meat and fruit consumption among Indian toddlers which could potentially explain some of the ethnic disparity observed in the prevalence of iron deficiency.

Another important micronutrient obtained from meat, and to a lesser degree eggs and milk, is vitamin B_{12} (Antony, 2000). Low meat eating dietary patterns are associated with low vitamin B_{12} concentrations and deficiency is problematic not only among South Asians in the Indian subcontinent (Antony, 2003) but also migrant communities in the UK (Chambers et al., 2000) and Canada (Gupta et al., 2004).

Higher homocysteine concentrations increase the risk of CVD, and have been demonstrated in young Indian children with low B_{12} (Hanumante et al., 2008). Furthermore, as reviewed earlier, vitamin B_{12} deficiency has been implicated in the epigenetic programming of obesity and is associated with an increased risk of GDM in pregnant women (Krishnaveni et al., 2009), and with increased risk of excess body fat and insulin resistance in offspring from B_{12} deficient pregnancies (Yajnik et al., 2008). The low meat consumption observed in Indian children in this study could potentially perpetuate the problem of B_{12} deficiency and the high rates of excess body fat, T2DM and CVD observed in this population. Further research is needed to examine the prevalence of vitamin B_{12} and iron deficiency among Indian children in NZ.

Ethnic differences were found in the type of protein toddlers consumed – for example European and Polynesian toddlers consumed more processed meat, Indian more lentils, and Asian more fish and eggs. Again, these differences highlight the need for nutrition messages to be tailored for different populations. Cultural factors which influence dietary patterns, such as vegetarianism in certain Indian populations, also need to be taken into account when making recommendations.

4.2.1.4 ***Milk and dairy products***

Overall, one out of five children in this study did not consume two or more servings of milk and dairy products per day; similar to the percentage in the ABC study (Theodore et al., 2006) and the CNS pilot study (Ministry of Health, 2001). Milk and dairy products are important for bone health in children (Chan et al., 1995; Black et al., 2002), and may protect against excess weight gain and obesity (Carruth et al., 2001; Skinner et al., 2003). Although not significant, less Asian children than any other ethnic group met the recommended two servings of milk and dairy products per day. As these figures did not include formula intake they may overestimate the number of Asian children not consuming milk and dairy products this often.

Although the MoH recommends after 2 years of age reduced-fat milk and dairy products be introduced to children's diets, only a small proportion of children in this and other studies in NZ consumed reduced-fat milk (Ministry of Health, 2001; Theodore et al., 2006; Rush et al., 2008a). Milk contributes 8% of the total fat in NZ school aged children's diets (Ministry of Health, 2003), and switching from full-fat to reduced-fat milk could potentially reduce children's fat and energy intake. Despite the popularity of milk as a beverage for toddler and preschool children, little research has examined the effect of full-fat as opposed to reduced-fat milk consumption on the risk of obesity. A recent US study of 850 preschoolers found no association between children's intake of full-fat versus reduced-fat milk at 2 years and risk of overweight at 3 years (Huh et al., 2010).

Similarly, little research has examined the effect of sweetened milk consumption on obesity risk in early childhood. Sweetened milk was a popular beverage for toddlers in this study, especially Polynesian and Indian children where more than half consumed sweetened milk at least twice a week (and from the 24-hour recall, more than one-third consumed sweetened milk during a typical day). Consistent with these results, Pacific children in the 2002 CNS were more likely to consume sweetened milk and milkshakes than European and other children (Ministry of Health, 2003); and a UK study found the addition of sugar and cereals to children's milk was more common among Asian (predominantly South Asian) mothers than European mothers (Williams et al., 2008). Children who consume sweetened milk have been shown to have higher sugar intakes than children who consume plain milk but better nutrient intakes than children who consume no milk at all (Murphy et al., 2008).

4.2.1.5 Other drinks

Asian toddlers were the greatest consumers of formula in this study, with more than half of Asian toddlers drinking formula at least twice a week, compared with around one in ten children from other ethnic groups. As mentioned previously, iron-deficiency is a problem among infants and toddlers and NZ, particularly in ethnic groups other than European. Although iron-fortified formula is a suitable follow on food from breast-milk for infants aged up to 12 months, in a policy statement on iron-deficiency in preschool children, Grant et al (2007b) suggest that a nutrient-rich diet as per the dietary guidelines is preferable to using iron-fortified drinks for children aged over 12 months. Whether the high prevalence of formula consumption in Asian toddlers is protective against iron deficiency requires further investigation.

In addition, the authors of this paper recommended that tea (which contains non-haem iron inhibitors) not be given to young children (Grant et al., 2007a). More than one in ten Polynesian, Indian and Asian toddlers consumed tea or coffee at least twice a week in this study, compared with less than one in twenty European toddlers. Again, the effect of tea consumption on iron deficiency in 2 year old children is an area that requires further investigation.

Exclusive breastfeeding is recommended until 6 months of age, and partial breastfeeding recommended until at least 12 months and beyond (Ministry of Health, 2008a). Among numerous other benefits, breastfeeding is thought be protective against overweight and obesity (Owen et al., 2005). Although breastfeeding duration has been associated with improved health outcomes in children, most studies have not examined the effect of breastfeeding beyond 12 months of age. Around one in ten Polynesian and Indian toddlers in this study were still breastfed at least twice a week – compared with one in twenty European and zero of eighteen Asian toddlers. The effect of such an extended period of breastfeeding on risk of obesity (and other health conditions) is not yet known.

4.2.1.6 Treat foods

The MoH recommends treat foods (as well as sweet drinks and takeaways) are consumed only occasionally (Ministry of Health, 1996), yet over three-quarters of toddlers in this study reported consuming treat foods at least once a day, and just under one-third reported consuming them at least twice a day. Similarly high levels of treat food consumption were observed among preschoolers in the ABC study, with biscuits and crisps the most popular treat foods consumed by children in both studies (Theodore et al., 2006). Treat foods tend to be high in fat, sugar or salt, and an Australian study of 16 to 24 months old toddlers, found 'extra' foods (i.e. energy-dense, nutrient-poor foods) contributed 20 to 30% of total daily energy intake and were negatively associated with the nutrient density of the child's diet (Webb et al., 2006).

4.2.1.7 Sweet drinks

A growing body of evidence supports a role for sweet drinks, in particular sugar sweetened drinks, in the development and maintenance of childhood obesity (Ludwig et al., 2001; Welsh et al., 2005; Faith et al., 2006; Dubois et al., 2007; Fiorito et al., 2009). Over a third of toddlers in this study consumed sweet drinks (juice or sugar sweetened drinks, such as cordial and soft drinks) at least once a day. Polynesian and Indian toddlers, the greatest consumers of sweetened milk, were also the most likely to consume sugar sweetened drinks and juice, respectively, at least twice a week. High levels sugar sweetened drink consumption among Pacific children have been reported in other NZ studies (Ministry of Health, 2003; Ministry of Health, 2008b).

4.2.1.8 Takeaways

Takeaway consumption is associated with increased energy intake and poorer diet quality in children (Bowman et al., 2004). Adults who consume takeaways twice a week or more have an increased risk of weight gain, overweight and obesity (World Cancer Research Fund American Institute for Cancer Research, 2007). Of concern were the high levels of takeaway consumption reported by toddlers in this study, with almost three-quarters of children consuming takeaways at least twice a week. These figures were higher than other NZ studies which have included similar ethnic groups (Ministry of Health, 2001; Ministry of Health, 2008b) For example, 7% of children aged 2 to 14 years reported consuming takeaways *three* or more times a week in the 2006/2007 NZ Health Survey, while 23% of toddlers reported consuming takeaways *five* times a week or more in this study. Takeaway consumption may have been overestimated as takeaways were calculated by summing eight FFQ food items (see methods chapter). Krebs-Smith (1995) demonstrated that the more questions asked about a food on a questionnaire, the higher its reported intake will be.

Nonetheless, the high takeaway consumption observed among Polynesian toddlers relative to other ethnic groups in this study was consistent with the 2006/2007 NZ Health Survey, where Pacific children aged 2 to 14 years were twice as likely as children in the total population to have consumed takeaways three or more times in the past seven days (Ministry of Health, 2008b).

4.2.2 Patterns of daily food consumption

4.2.2.1 Number of eating occasions

Snacking and regular meals are important for young children, who may not be able to obtain all the nutrients they need from main meals alone. Toddlers in this study had on average seven eating occasions per day, the same as toddlers in the US Feeding Infants and Toddlers study. Increased meal frequency may be associated with a decreased risk of obesity (Toschke et al., 2005a), although the evidence is limited in children. Indian and Asian toddlers in this study had on average one more eating occasion per day than European toddlers.

4.2.2.2 Foods consumed meals and snacks

Ethnic differences were observed in the types of foods children consumed at meals. Indian and Asian children in this study tended to have more rice based diets, while European and Polynesian children consumed more bread and potatoes. The daily meal patterns of Asian toddlers in this study was consistent with another study of Asian preschoolers in NZ, where bread, eggs and noodles were popular breakfast foods; and rice, vegetables, meat, fruit and eggs were commonly consumed at lunch and dinner (Soh et al., 2000).

In contrast to the meal patterns observed in the US Feeding Infants and Toddlers study (Skinner et al., 2004), fruit was the most popular snack among children from all ethnic groups in this study. Other popular snack foods for toddlers in this study included biscuits, crackers, crisps, cheese, and yoghurt. The types of snack foods consumed by children were similar among ethnic groups, although crisps were only consumed by

Polynesian and Indian children. As between meal snacks make a high contribution to children's overall energy and sugar intakes (Brinsdon et al., 1992; Ziegler et al., 2006), it is recommended that high-fat and high-sugar foods are eaten only occasionally (Ministry of Health, 1996). Snacks could provide an ideal time for parents to increase toddler's intakes of breads and cereals, fruit, vegetables and milk and dairy products.

Patterns of beverage intake also appeared to be different among ethnic groups, consistent with what was observed in the FFQ – for example the highest number of Polynesian children consumed sugar sweetened beverages during a typical day, the highest number of Asian toddlers consumed formula and the highest number of Polynesian and Indian toddlers consumed sweetened milk. These results were discussed earlier in the chapter.

4.2.3 Validation of the FFQ with the 24-hour recall

There is no method for measuring the diets of free-living subjects with absolute precision, and as such, there is no true validation standard. Studies validating methods of measuring dietary intake are therefore comparative studies, where the results of one method of measuring dietary intake are compared with another (Serdula et al., 2001). In this study, foods were ranked in order of the number of children who reported consuming the food at least once during a 'typical' day on the 24-hour food recall, and compared with the order of children who reported consuming the food at least twice a week on the FFQ. This frequency of consumption was selected as 'at least twice a week' corresponded to 'two to four times a week' or more on the FFQ. Consuming a food four times a week could be considered as consuming the food during a typical day, however this frequency also included foods only consumed twice a week and therefore the number of children consuming each food was consistently higher for the FFQ than the 24-hour food recall.

The top ten foods consumed by children were the same between both methods, with the exception of crackers – which were not included on the FFQ, but reported by one-third of children during on the 24-hour recall. The 24-hour recall was helpful in identifying other foods consumed by children during a typical day that were not included on the FFQ. As most of the foods missed by the FFQ but picked up by the 24-hour food recall could be classified as treat foods (crackers, ice-cream, muffins, ice blocks, jelly and chicken nuggets), the number of children consuming treat foods once or twice a day could have been underestimated by the FFQ.

A problem with comparing 24-hour food recalls with FFQs is that they are both respondent-based methods, and therefore likely to suffer from the same errors (Willett, 1998). Ideally, respondent based methods of measuring dietary intake would be compared with physiologic methods, such as biochemical markers, which would not be subject to the same respondent based errors (Bingham, 1994). However, as the aim of this study was to examine food patterns (by ranking foods) rather than examine actual energy or nutrient intake, the validity of the FFQ for ranking foods and food groups appeared to be acceptable.

4.2.4 Patterns of daily activity

European toddlers slept on average 13 hours per 24 hour period, 1 hour longer than Polynesian, Indian and Asian children in this study. Short sleep duration has been associated with childhood obesity in a number of studies. Taveras et al (2008) reported that BMI z-score at 3 years of age was positively associated with sleep duration of less than 12 hours during infancy (6 to 24 months). Around four out five European toddlers slept for 12 or more hours per 24-hour period in this study, significantly more than any other ethnic group. Less than half of Indian and Polynesian toddlers slept this long. In addition to the amount of sleep, the timing of sleep may also be important for children, as later bedtimes have been associated with an increased risk of obesity (Sekine et al., 2002a; Snell et al., 2007a). On average, European toddlers in this study went to bed 1.5 hours earlier than toddlers from other ethnic groups.

Time spent watching TV has been linked with an increased risk of obesity in children (Dennison et al., 2002; Reilly et al., 2005a). Toddlers in this study watched on average one hour of TV a day, with European children watching around 25 to 30 minutes less TV a day than other ethnic groups. In the Avon longitudinal study, watching more than 8 hours of television per week at age 3 was associated with an increased risk of obesity at age 7 (Reilly et al., 2005a). This is concerning as Indian and Asian two-year olds in this study already watched more than 8 hours of TV a week on average, and Polynesian children watched close to this amount.

There is no explicit recommended level of physical activity for 2 year old children in NZ, and toddlers in this study appeared to be adequately active, spending almost 5 hours a day in active play. Some researchers suggest however, that although young children are perceived to be active, recent changes to environments may have led to decreases in young children's physical activity levels (Boreham et al., 2001). Physical activity in preschoolers is characterized by intermittent short bouts of activity (Timmons et al., 2007). The method used to measure activity in this study (24-hour activity recall) is not able to capture such activity, and may not have accurately measured physical versus sedentary time in these children. No ethnic differences were observed in the time toddlers spent in active play in this study.

In summary, Polynesian, Indian and Asian toddlers appear to have a more obesogenic activity pattern than European toddlers, characterized by shorter sleeping hours, later bedtimes and more time spent watching TV. The results of this study are consistent with overseas studies, which have found significant ethnic differences in the time children spend sleeping (Liu et al., 2005) and watching TV (Dennison et al., 2002). The tracking of these patterns through childhood, and their association with later obesity are areas that warrant further investigation.

4.3 Section B: Body composition

An individual's body composition affects their risk of disease throughout their life course, and obese children tend to suffer from similar co-morbidities as obese adults, including insulin resistance and dyslipidaemia (Freedman et al., 1999). Once obesity has developed in preschoolers it tends to persist into later childhood and adolescence (Nader et al., 2006), and accurately identifying young children who are overweight or obese is therefore of utmost importance. Sex and ethnic differences in body composition were identified among 2 year olds in this study and are discussed below.

Boys were slightly taller and heavier than girls in this study, although the differences were not significant, and for a given height and weight, girls were significantly fatter than boys. These results are consistent with previous research in young children, which has shown boys are taller and heavier than girls from birth, and although both sexes have a similar FM, girls are proportionally fatter because of a smaller FFM (de Bruin et al., 1996). In this study, boys not only had on average 0.7kg more FFM than girls at 2 years, but also 0.4kg less FM, and therefore a body fat percentage that was 3% lower.

Overall, children in this study had height-for-age z-scores close to zero, yet weight-for-age and BMI-for-age z-scores above zero - indicating that despite being a similar height, these toddlers were heavier than the average WHO child (WHO Multicentre Growth Reference Study Group, 2006a). Whether this was because these children were exposed to GDM in utero could not be determined due to lack of a control group. Only Polynesian children had weight-for-age and BMI-for-age z-scores significantly different to zero. The weight and BMI z-scores for Polynesian children in this study (1.26 and 1.38) were high - similar to those reported by Rush et al (2008b) for Pacific 2 year olds (weight-for-age z-score 1.69 and BMI for-age z-score 1.97), and Gordon et al (2003) for Pacific 3 to 7 year olds (BMI-for-age z-score 1.33).

In the 2002 CNS, Pacific children were five times as likely to be obese as children from other ethnic groups (Ministry of Health, 2003). Similarly, Polynesian toddlers in this study were significantly taller and heavier than all other ethnic groups and had two, three and four times the prevalence of obesity of Asian, European and Indian toddlers, respectively, when international BMI cut-off points were used (Cole et al., 2000). Polynesian toddlers had 2% more body fat than European toddlers, and findings from this and other studies of Pacific infants, toddlers and preschoolers suggest Pacific children are on a trajectory of overweight and obesity from birth (Gordon et al., 2003; Rush et al., 2008b).

However, BMI cut-off points used to define overweight and obesity may misclassify Pacific and Asian populations, who have been shown to have less and more FM, respectively, than European populations for a given height and weight (Swinburn et al., 1996; Deurenberg et al., 1998). Lower BMI cut-off points have been proposed to account for the low lean-to-fat ratio observed in Asian populations (World Health Organisation Expert Consultation, 2004), and higher BMI cut-off points to the high lean-to-fat ratio observed in Polynesian populations (Swinburn et al., 1999).

Clear ethnic differences in body composition were observed among toddlers in this study, suggesting ethnic variation in body composition is present from a young age. Although Indian toddlers had significantly lower BMI values than European and Polynesian toddlers, for a given height and weight they had on average 0.3 kg more FM and less FFM. This 'thin-fat' phenotype appears to be present in Indian populations from birth, and may predispose Indian children to an insulin-resistant state (Yajnik et al., 2003).

Furthermore, within Asian populations, ethnic specific cut-off points may be needed, as Indian Asians have been found to have a greater FM than Chinese and Malay Asians at a given height and weight (Hughes et al., 1997). Consistent with this observation, after adjusting for height and weight, Asian (predominantly Chinese) toddlers in this study had a greater FFM and smaller FM than Indian toddlers, although the difference did not reach statistical significance - possibly due to the small sample size.

As the ethnic diversity of NZ is increasing, with Asian (including Indian Asian) the fastest growing ethnic group (Statistics New Zealand, 2008), accurately identifying children at risk of obesity and obesity related diseases is important. Indian adults have higher rates of T2DM than the general population (Ministry of Health, 2006), and the prevalence of overweight and obesity in children from this ethnic group may be underestimated in NZ health surveys - which have relied on international BMI cut-off points. The results of this study support the use of ethnic specific BMI cut-off points from a young age, but more studies are needed to understand if there are ethnic differences in the relationship of body fatness with actual disease risk factors.

4.4 Section C: Associations among food and activity patterns, body composition, maternal GDM treatment and maternal glucose control

4.4.1 Associations between food and activity patterns and body composition

No associations between food and activity patterns and body composition at 2 years of age were identified. This may have been due to the methods used in this study. As serving sizes were not measured, portion sizes and the amount of food children consumed could not be examined, and activity recalls are not as accurate as objective measures of activity such as accelerometer and pedometers in measuring young children's physical activity patterns (Oliver et al., 2007). Alternatively, the lack of association found could suggest factors such as a child's genetic background, the intrauterine environment they were exposed to and whether or not they were breastfed are greater predictors of body composition at 2 years of age than diet and activity. Lanigan et al (2010) have suggested 30 to 50% of the predisposition towards obesity in preschool children can be explained by genetic factors alone.

With weaning occurring at around 4 to 6 months of age and the introduction of certain foods such as cow's milk not recommended until 1 year of age, the body composition (i.e. FM) of toddlers in this study may not have had adequate time to be greatly influenced by food patterns at 2 years. Whether food and activity patterns predict body composition in later childhood, as has been observed in other studies (Reilly et al., 2005a; Welsh et al., 2005), is of interest and could be examined when children are followed up at 5 and 7 years of age.

Despite the lack of a direct association between food and activity patterns and body composition, this study provided some evidence that Polynesian and Indian toddlers, ethnic groups known to have high rates of excess body fat and T2DM as adults (World Health Organisation Expert Consultation, 2004; Ministry of Health, 2006; Ministry of Health, 2008b), have more obesogenic food and activity patterns at 2 years of age. For example, less Indian than European children consumed fruit at least twice a day, more Polynesian than European children consumed takeaways at least five times a week; and both ethnic groups (along with Asian) had shorter sleeping hours, later bedtimes and spent more time watching TV. Polynesian children were fatter than European toddler at 2 years of age, and Indian toddlers were proportionally fatter than European toddlers adjusted for height and weight.

As mentioned above, genetic and intrauterine influences may explain the ethnic differences in body composition observed among these children. All children in this study were from mothers with GDM; however a significantly greater proportion of Polynesian than European and Indian children were born to mothers in the worst tertile of glucose control. Exposure to a high maternal glucose concentration is thought to program obesity in offspring (Hillier et al., 2007a), however associations between maternal glucose control and body composition are being analysed elsewhere.

Another possible intrauterine influence is exposure to low maternal B_{12} concentrations, which as mentioned previously, have been associated with increased adiposity and insulin resistance in offspring (Yajnik et al., 2008). Deficiency in B_{12} has also been recently associated with an increased risk of GDM in women (Krishnaveni et al., 2009). As the prevalence of GDM among Indian women at National Women's Hospital in 2008 was more than five times that of European women (Auckland District Health Board, 2008), the relationship between maternal B_{12} concentrations, GDM and offspring adiposity is an area that warrants further investigation. A low meat eating dietary pattern was identified among Indian preschool children in this study, which could potentially perpetuate the problem.

4.4.2 Associations between maternal GDM treatment, maternal glucose control and food and activity patterns

No differences in food and activity patterns were found by maternal glucose control during pregnancy. These results do not rule out an effect of maternal glucose concentrations on diet and physical activity in offspring. Postnatal hyperphagia and decreased physical activity have been demonstrated in animal offspring exposed to a nutritionally adverse postnatal environment (Vickers et al., 2000; Vickers et al., 2003). As the amount of food consumed by children was not measured in this study, the effect of maternal glucose concentrations on energy intake in offspring could not be determined. As mentioned above, the method used to measure physical activity may not have accurately measured the time children spent active versus sedentary.

Similarly, no differences in the food and activity patterns of offspring were found by maternal GDM treatment, and the results of this study therefore support the use of metformin as a safe alternative treatment to insulin for GDM.

4.5 Limitations

A limitation of this study was the relatively small number of Asian participants (18), which may not have allowed ethnic differences in food patterns and body composition to reach statistical significance. A further limitation was that Maori participants were combined with Pacific, although these ethnic groups have different food patterns, as demonstrated in the 2002 CNS (Ministry of Health, 2003). To address the high prevalence of obesity and associated health conditions among Maori in NZ, future research is needed examine the food and activity patterns of toddlers in this ethnic group.

A further limitation of this study was that socioeconomic status, an important predictor of childhood obesity (Wang, 2001) was not addressed.

The methods used to measure food and activity patterns (FFQ and 24 hour food and activity recall) are not as accurate as other methods such as pedometer and accelerometer measured activity (Oliver et al., 2007). The methods used in this study involved participant (in this case, parental) recall, the accuracy of which is reliant on the respondent's memory and may be subject to bias (Trabulsi et al., 2001; Oliver et al., 2007) . As the amount of food children consumed was not measured, energy intake could not be calculated. This could explain why no associations between food and activity patterns and body composition, or maternal glucose control and food and activity patterns were identified in this study.

This study was not powered to detect a difference in body composition by food and activity patterns adjusted for sex and ethnicity (i.e. there were not an adequate number of participants in each cell). Because of the number tests being run when examining associations among food and activity patterns, body composition and maternal glucose control, the significance level was lowered to 0.01 (1%) to reduce the chance of a type I error. However, a type II error (false negative) may have resulted due to the small sample size.

Finally, as the children in this sample had all been exposed to GDM during gestation, food and activity patterns and body composition identified in this study may be different to those of the general population. The effect of being exposed to GDM on food and activity patterns and body composition could not be examined due to lack of a control group. The study here did not examine associations between maternal GDM treatment, glucose control and body composition at 2 years, which are being examined elsewhere.

4.6 Strengths

This is the first NZ study to examine and compare food and activity patterns and body composition in a multiethnic sample of 2 year old children. A strength of this study was the ethnic diversity (33% European, 28% Polynesian, 25% Indian, 12% Asian and 3% Other). The food and activity patterns of ethnic groups other than European are becoming increasingly relevant as a) the ethnic diversity of NZ is increasing (Statistics New Zealand, 2008), and b) ethnic groups other than European tend to have higher rates obesity and T2DM (Ministry of Health, 2008b). The results of this study could be used to inform future public health recommendations for at risk ethnic groups.

Although semi-abbreviated FFQs and 24-hour food recalls may not be as accurate as other methods in quantifying energy and nutrient intake, they are useful for ranking foods (Serdula et al., 2001). As two methods were used to assess food patterns, the results from each method were able to be compared, providing some measure of internal validity.

This is the first study in NZ to measure body composition in a multiethnic sample of 2 year old children by BIA and DEXA, and to develop a BIA equation validated by DEXA measurements. This equation could be used in future studies of NZ preschool children, as equations are specific for the population they were developed in. Furthermore, the use of BMI as a surrogate marker of body fatness may not be appropriate when comparing ethnic groups (Pacific and Asian groups in particular) due to ethnic variation in body composition. A strength of this study was that body fatness was assessed using BIA, a more direct measure of body fat than BMI.

Finally, as this study was part of a longitudinal study of the offspring of mothers treated for GDM, the results of this study regarding food and activity patterns and body composition at 2 years could be compared with the health outcomes of children at ages 5 and 7 years.

4.7 Conclusions and recommendations

This is the first study to examine and compare food and activity patterns and body composition in NZ European, Polynesian, Indian and Asian 2 year old children. For the total sample, toddlers were least likely to meet the recommended servings of breads and cereals, fruit and vegetables each day, and the most likely to consume the recommended servings of meat and other protein. Although the MoH food and nutrition guidelines for 2 year old children state that high-fat and high-sugar foods should be consumed only occasionally, around three-quarters of toddlers consumed treat foods daily and takeaways at least twice a week; and more than one-third consumed sweet drinks daily. Based on BMI cut-off points, one in ten toddlers were classified as thin, one in five overweight, and one in twenty obese.

The main findings of this study were the marked differences among ethnic groups. Compared with European toddlers, significantly less Indian toddlers consumed fruit at least twice a day and meat at least once a day, and significantly more Polynesian toddlers consumed takeaways and fries at least five times a week. Although the differences did not all reach statistical significance, compared with European, more Polynesian children consumed sugar sweetened drinks, more Indian children consumed juice, and more Polynesian and Indian children consumed sweetened milk at least twice a week. Polynesian and Indian toddlers, along with Asian toddlers, also had more obesogenic activity patterns than European toddlers – characterised by shorter sleeping hours, later bedtimes and more time spent watching TV.

Marked differences in body composition were also identified among ethnic groups, as well as between boys and girls. Despite being a similar size, girls in this study were fatter than boys. Polynesian toddlers were taller and heavier than other ethnic groups and significantly fatter than European toddlers. Correspondingly, the highest percentages of Polynesian toddlers were classified at overweight and obese, while the highest percentage of Indian toddlers was classified as thin. However, for a given height and weight, Indian toddlers were proportionally fatter than European and Polynesian toddlers. These findings are consistent with previous research in older children and adults, and suggest Polynesian and Indian children are on a trajectory of excess body fat from an early age.

Although this study failed to identify any associations between food and activity patterns and body composition at 2 years of age, ethnic differences in food and activity patterns and body composition demonstrated in this study may explain the genesis of the disparity in the prevalence of obesity and associated diseases later in life. Future research could examine the tracking of food and activity patterns in these children and associations with body composition and disease risk factors (e.g. insulin sensitivity and blood pressure) at a later age.

Furthermore, as the children in this study were exposed to GDM during gestation, they may be at an increased risk of obesity and T2DM. Research is needed to identify food and activity patterns that may overcome the risk of obesity in these children, as the number of children exposed to GDM and lower levels of maternal hyperglycaemia is likely to rise in the upcoming years. Although no effect of maternal glucose control on offspring food and activity patterns was observed in this study, evidence from animal models suggests postnatal diet and activity may be programmed by the maternal nutritional environment. It would be interesting to examine whether the food and activity patterns of children in this study are different to those of children in the general population. Inclusion of a control group when these children are followed up at 5 and 7 years would allow patterns to be compared between the two groups.

This study also identified differences between ethnic groups in meal patterns and the types of individual foods consumed. Many of these differences were consistent with traditional diets, such as the consumption of roti and chappati by Indian toddlers, and taro by Polynesian toddlers. In fitting with a traditional dietary pattern, Indian and Asian children tended to have meals based more around rice, while European and Polynesian children consumed more bread and potatoes at meal times. These differences need to be taken into account when making public health recommendations, and illustrate the importance of tailoring nutritional interventions for different populations.

In conclusion, this study has identified differences in food and activity patterns and body composition in young children that could contribute to the ethnic disparity in the prevalence of obesity and related diseases. The ethnic diversity of NZ will increase in the upcoming years, as will the number of children exposed to GDM. With food and activity patterns and body composition shown to track from an early age, interventions aimed at preventing obesity may need to begin early in life and be sustained throughout the life course.

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APPENDICES

Appendix 1: Ministry of Health food and nutrition guidelines

Adapted from Ministry of Health (1996)

Eating for Healthy Children (2-12 years)

Vegetables and Fruit

- Vegetables and fruit have carbohydrates (sugar and starch), fibre, vitamins and minerals.

Preschoolers: eat at least two servings of vegetables and two servings of fruit every day.

Breads and Cereals

- Breads, cereals and rice are high in carbohydrates and fibre.
- Preschoolers have small stomachs and cannot eat the same amount of fibre as older children or adults. Increase fibre gradually with a variety of vegetables, fruit, bread and cereals.

Preschoolers: Eat at least four servings every day.

Milk and Milk Products

- Children and preschoolers need milk and milk products for protein and calcium.
- After two years of age gradually introduce reduced and low fat milk and milk products.

Preschoolers: Eat at least two to three servings every day.

Lean Meats, Chicken, Seafood, Eggs and Dried Peas, Beans and Lentils

- These foods have protein, vitamins and minerals, including iron and zinc.
- Young children need iron. Lean red meats, seafood and chicken have lots of iron.

Preschoolers: Eat at least one serving every day.

Appendix 2: Semi-abbreviated FFQ

Frequency: For each of the food items listed in the table below, answer as follows:

a) Never
b) Once a month
c) Once a week
d) 2-4 times weekly
e) 5-7 times weekly
f) 2-3 times a day
g) 4 or more times a day

Food item	***Frequency (a-g)***	***Brand Name***
Blue top/full cream milk		
Light blue top milk		
Green or yellow top milk		
Sweetened milk (e.g. choc., strawberry, milo)		
Soy milk		
Breast milk		
Formula		
Juice		
Sugary drinks (cordial e.g. ribena, other concentrates, fizzy drinks)		
Tea or coffee – no sugar		
Tea or coffee with sugar		
Water		
White bread		
Brown bread - smooth		
Brown bread- grainy		
Potato – boiled		
Potato – mashed		
Potato – fries		
Kumara		
Taro		
Plantain (green banana)		
White rice		
Brown rice		
Dumplings		
Noodles		
Pasta		
Roti		
Chappati		
Naan		
Breakfast cereal – non sugary		
Breakfast cereal - sugary		
Food item		
Biscuits – plain		
Biscuits – chocolate/icing		
Muesli bar/snack bar		
Chocolate bar		
Lollies		

Crisps/chippies		
Pizza		
McDonald's/Burger King/Wendy's		
KFC		
Fish and chips		
Chinese takeaway		
Indian takeaway		
Other takeaway		
Other energy dense food not listed __________		
Dried fruit		
Fresh Fruit		
Tinned fruit – natural juice		
Tinned fruit - syrup		
Vegetables - green		
Vegetables – red/orange (e.g. carrots, pumpkin, capsicum)		
Vegetables - other		
Processed meat (eg salami, sausages)		
Red meat (e.g. beef, lamb)		
Other meat (e.g. chicken,pork)		
Fish fingers/crumbed/battered		
Fish		
Cheese		
Cheese sauce		
Yogurt – unsweetened natural		
Yogurt – sweetened/ fruit		
Egg		
Lentils		
Beans e.g. kidney beans/baked beans		
Other		

Appendix 3: Sample of 24-hour food and activity recall

Detailed day: diet and activity

The following is to gauge a pattern of food and activity for your child on a typical day.

For the activity, indicate whether outdoors (O) or indoors (I) in correct box.

Activity Food and Drink Record

Time	Activity						Food and drink	Amount
	Sleeping	TV or Video	Sitting	Quiet play	Physically active	Other (detail)		
6am								
7am								
8am								
9am								
10am								
11am								
12noon								
1pm								
2pm								
3pm								
4pm								
5pm								

Appendix 4: Development of a BIA equation to predict FFM

Body composition was measured by DEXA scans, when possible, on children in the total sample. Of the 146 children who completed BIA measurements, 77 children also completed good quality DEXA scans (i.e. without movement artefacts). DEXA FFM was calculated as the sum of LM and BMC. DEXA FFM was used as the criterion for the development of a prediction equation by multiple regression analysis based on the following predictor values: weight, height²/ resistance, sex (dummy coded with girls = 0 and boys = 1) and age (presented in Table 1 below).

Table 1. Variables used to develop a BIA equation to predict FFM, by sex and ethnicity

		European (n = 32)	Polynesian (n = 20)	Indian (n = 14)	Asian (n = 13)	Other (n = 3)
Girls	**n**	15	11	4	9	3
	DEXA FFM (kg)	10.3 ± 1.1	11.8 ± 1.2	9.3 ± 0.9	10.2 ± 0.8	11.2 ± 1.4
	Height (cm)	86.9 ± 4.4	91.8 ± 5.0	87.2 ± 4.7	88.2 ± 4.9	90.7 ± 4.3
	Resistance (Ω)	732.8 ± 62.3	724.1 ± 63.8	865.5 ± 102.9	787.5 ± 68.8	746.2 ± 46.7
	Weight (kg)	12.9 ± 1.1	14.7 ± 2.1	11.1 ± 1.3	12.9 ± 1.1	13.4 ± 1.1
	Age (months)	26.7 ± 2.6	29.2 ± 3.7	26.7 ± 1.8	28.1 ± 2.6	28.3 ± 4.2
Boys	**n**	12	9	10	4	0
	DEXA FFM (kg)	11.4 ± 1.8	12.0 ± 1.1	10.7 ± 1.5	10.4 ± 1.1	N/A
	Height (cm)	89.1 ± 6.2	91.2 ± 5.0	90.1 ± 3.7	86.4 ± 2.4	N/A
	Resistance (Ω)	731.8 ± 64.1	706.6 ± 62.7	805.6 ± 85.9	737.0 ± 58.3	N/A
	Weight (kg)	13.6 ± 2.4	14.5 ± 1.2	13.0 ± 2.6	12.6 ± 1.7	N/A
	Age (months)	27.3 ± 2.1	28.6 ± 3.2	28.5 ± 2.8	27.2 ± 2.9	N/A

Values are mean ± standard deviation; FFM = fat free mass; cm = centimetres; Ω = ohms; kg = kilograms; N/A = not applicable.

The resulting BIA equation is presented below.

Equation to predict FFM from height, resistance, weight, sex and age:

$$\mathbf{FFM_{DEXA}\ kg = 0.894 + 0.421H^2/R + 0.268Wt + 0.338Sex + 0.064Age}$$

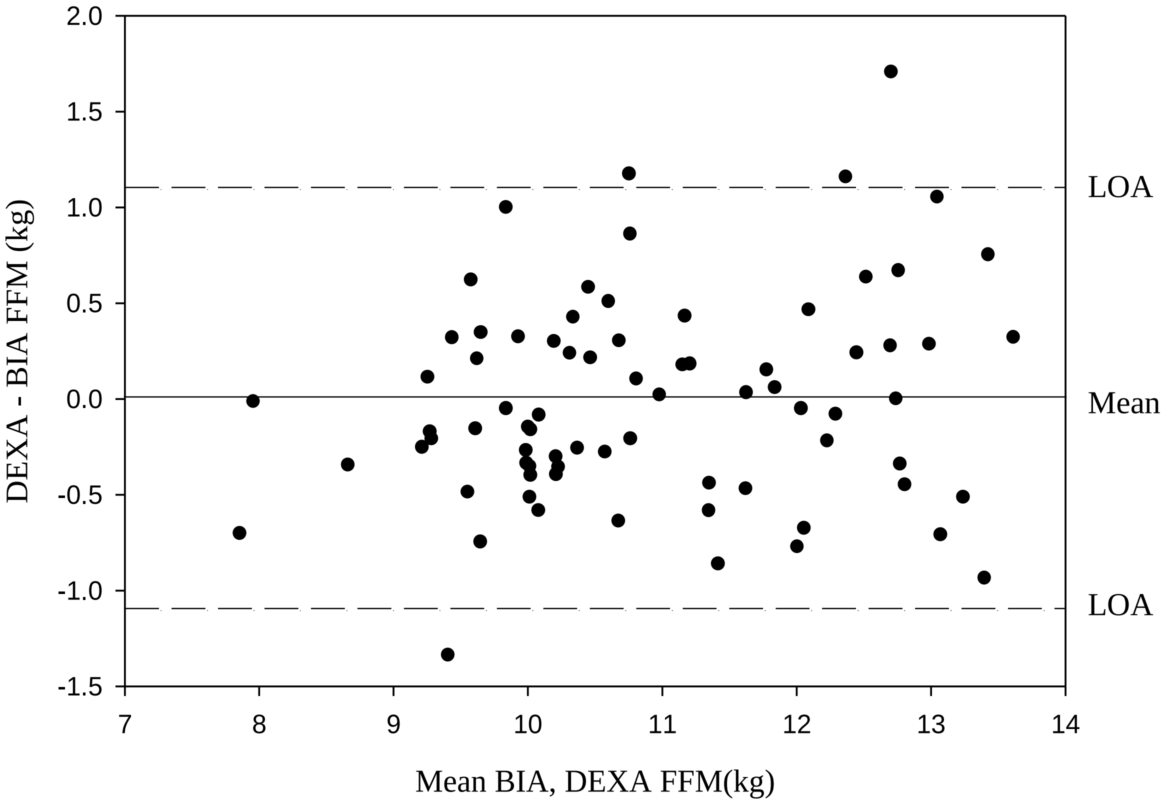
$$\mathbf{R^2 = 0.857 \qquad SEE = 0.559\ kg}$$

H = height, cm; R = resistance, Ω; Age = age, months; Wt = weight, kg; Sex = 0 female, 1 male

The difference between measured and predicted values (bias, tested against zero using paired t-test), was not significant ($p=0.80$) and the dependency of the bias on the mean of measured and predicted values was also not significant ($r = 0.20$, $p = 0.09$).

The limits of agreement (LOA) between the two methods were determined using the technique of Bland and Altman. The mean difference between the two methods (DEXA FFM – BIA FFM) was 0.0161, and the standard deviation was 0.544, with the LOA therefore 1.1 kg and -1.1 kg (illustrated in Figure 1). There was some evidence of increased variation in the agreement between the two methods at a FFM of > 11 kg.

Figure 1. Bland-Altman plot of the difference between DEXA measured and BIA predicted FFM by mean BIA and DEXA FFM in 77, 2-year old children.



DEXA = dual energy x-ray absorptiometry; BIA = bioimpedance analysis; FFM = fat free mass; LOA = limits of agreement; kg = kilograms.

This equation was applied to all 146 children who completed BIA and anthropometric measurements using resistance, height and weight and age and sex measurements. Measurements for the total sample were not significantly different than for the sample of 77 children in which the equation was developed. The resulting values for FFM and FM (calculated as FFM subtracted from weighed weight) are presented in the main body of the thesis. Two participants who only had BIA measured had derived FM values that were outliers (<5% body fat) and were removed from the data set, bringing the total participants to 144.

Appendix 5: FFQ foods included in the FFQ and 24-hour food recall validation

The table presents 24-hour recall foods and the corresponding FFQ food items were combined to allow for comparison between the two methods.

24 –hr food recall food	FFQ foods
Fruit	Fresh fruit, dried fruit, canned fruit in juice, canned fruit syrup
Vegetables	Green/ red and orange/ other vegetables, kumara, taro, plantain
Milk	Full-fat milk, reduced-fat milk, low-fat milk
Meat	Red meat, other meat, processed meat
Bread	White bread, smooth brown bread, grainy brown bread
Cereal	Non-sugary breakfast cereal, sugary breakfast cereal
Rice, noodles or pasta	White rice, brown rice, noodles and pasta
Biscuits	Plain biscuits, choc icing biscuits
Yoghurt	Sweetened yoghurt, unsweetened yoghurt
Crackers	N/A – not included on the FFQ
Cheese	Cheese
Juice	Juice
Potatoes	Mashed potatoes, boiled potatoes
Sweetened milk	Sweetened milk
Crisps	Crisps
Egg	Eggs
Formula	Formula
Sugar sweetened drinks	Sugar sweetened drinks
Lentils and beans	Lentils, beans
Fish	Fish
Roti or chappati	Roti, chappati
Ice-cream	N/A – not included on the FFQ
Breast milk	Breast milk
Muesli bar	N/A – not included on the FFQ
Muffins	N/A – not included on the FFQ
Nuts	N/A – not included on the FFQ
Ice block	N/A – not included on the FFQ
Lollies	Lollies
Jelly	N/A – not included on the FFQ
Fish fingers	Fish fingers
Chicken nuggets	N/A – not included on the FFQ