Determining the Relative Validity and Reproducibility of a Complementary Food Frequency Questionnaire to Assess Nutrient Intake in New Zealand Infants aged 9 to 12 months

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Abstract

Background: Obtaining information on dietary intake in infants is challenging but necessary to help understand the relationship between diet and growth and development. Food frequency questionnaires (FFQ) are commonly used to investigate dietary intake as they are suited for use in large population groups, can determine intake over multiple days and minimise participant and researcher burden, and associated costs. FFQs need to be specific to the population they are to be used in and validated so that their results can be interpreted with greater confidence. There are currently no simple, validated dietary assessment methods that are available to assess nutrient intake for New Zealand infants.

Objective: To validate a complementary food frequency questionnaire (CFFQ) against a reference method of a four-day weighed food record (4dWFR) for assessing nutrient intakes of New Zealand infants aged 9 to 12 months. A secondary objective was to assess the reproducibility of the CFFQ by having it completed on two separate occasions, four weeks apart.

Methods: A cross-sectional study design was used including ninety-five infants aged 10 ± 1 months and their primary caregiver, who completed the CFFQ twice (CFFQ-1 and CFFQ-2), approximately four weeks apart (to assess reproducibility). Four days of weighed food records (4dWFR) were collected on non-consecutive days between CFFQ administrations (validity). Validity and reproducibility were assessed for intakes of energy, macronutrients and micronutrients using paired t-tests, Pearson's correlation coefficients, cross-classification and Bland-Altman analysis. Two data sets were created, one that included milk intake (breast milk and formula) and one that excluded milk intake. The data was also adjusted for energy intake, before being reassessed for validity and reproducibility.

Results: For validity, most nutrient intakes from the CFFQ were comparable to the 4dWFR (range <1% up to 27% different). The CFFQ produced significantly higher nutrient intakes for fat and saturated fat, but significantly lower nutrient intakes for carbohydrate, fibre, folate, potassium, thiamin, riboflavin, niacin and vitamin C (p<0.01). Correlation coefficients ranged from r=0.18 (saturated fat) to r=0.81 (iron; mean r=0.52). Over half of participants had the same tertile classification by both the 4dWFR and the

CFFQ (mean 53.9%, range 39.0% (selenium) to 67.4% (iron)). Between 2.1% (iron and calcium) and 14.7% (saturated fat) of participants (mean 7.1%) were misclassified into opposite tertiles. Most of the nutrients showed acceptable agreement between methods (κ=0.20–0.60). Saturated fat and selenium showed poor agreement (κ<0.20) and iron showed good agreement (κ>0.60). Removing milk intake weakened the correlations (range r=0.21 for vitamin E to r=0.60 for niacin, mean r=0.44) and reduced the agreement between methods (50.3% correctly classified and 9.2% grossly misclassified). Adjustment for energy intake showed comparable correlation coefficients (range r=0.24 for fibre and r=0.78 for calcium and iron, mean r=0.52) and improved the agreement between methods (56.2% correctly classified and 6.8% grossly misclassified). The CFFQ had adequate performance for reproducibility for all nutrients and energy with acceptable correlations (r≥0.20) and good cross-classification (>50% correctly classified and <10% grossly misclassified) apart from fat and saturated fat (40.9% and 47.3% correctly classified, respectively). All nutrients showed acceptable to good agreement between the CFFQ-1 and CFFQ-2 (κ>0.20). When milk intake was excluded and when the data was adjusted for energy intake, there was comparable acceptable to good correlations and cross-classification.

Conclusion: Although there were some differences in absolute energy and nutrient intakes between the methods, the CFFQ appears to have acceptable validity for assessing 14 nutrients and good reproducibility for assessing 18 nutrients and energy in infants aged 9-12 months. The CFFQ could be used in future research to investigate infant nutrient intakes where using a simple tool with little participant burden is beneficial.

Keywords: infant, dietary assessment, reliability, validation, questionnaire, nutrient

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Table of contents

Lists of tables

Chapter 1.

Chapter 2.

Chapter 3.

Supplementary results tables

List of figures

Chapter 3.

Appendices

Abbreviations

24HR	Twenty-four hour recall
4dWFR	Four-day weighed food record
7dWFR	Seven-day weighed food record
CFFQ	Complementary food frequency questionnaire
CFFQ-1	First Complementary food frequency questionnaire (week 1)
CFFQ-2	Second Complementary food frequency questionnaire (week 4)
CI	Confidence intervals
FFQ	Food frequency questionnaire
κ	Kappa statistic (statistical analysis)
LOA	Limits of agreement
NIP	Nutrition information panel
NRV	Nutrient Reference Values
NZ	New Zealand
p	p-value (statistical analysis)
r	Correlation coefficient (statistical analysis)
SD	Standard deviation
Tbsp	Tablespoon
tsp	Teaspoon
WFR	Weighed food record
<	Less than
≤	Equal to or less than
>	Greater than
≥	Equal to or greater than

Chapter 1. Introduction

1.1 Background

Nutrient intake and growth in infancy have been shown to impact health in later life. Rapid early weight gain, early cessation of breastfeeding and high protein intakes in infancy have all been shown to have an influence on adiposity in adulthood (Baird et al., 2005; Barker, Osmond, Forsen, Kajantie, & Eriksson, 2005; Günther, Buyken, & Kroke, 2007; Koletzko et al., 2009; Owen, Martin, Whincup, Smith, & Cook, 2005). Obesity effects one in three adults and one in eight children with rates on the rise in New Zealand (NZ) (Ministry of Health, 2017). Obesity is just one of the many reasons why gathering information on dietary quality and adequacy in young children is important and could assist with furthering our understanding of the links with growth and development, as well as reducing risk factors for future health issues.

Dietary intake in infants is highly transitional compared to adults. Infancy is the only time in the lifecycle when there is reliance on one food. Infants change from a diet consisting entirely of milk (breast milk and/or infant formula) to one consisting of a variety of foods. This gradual introduction of solid food is commonly known as weaning, but the term *complementary feeding* is preferred as it encompasses the introduction of foods to complement the nutrient intake provided by breast milk or infant formula to ensure appropriate growth and development (Ministry of Health, 2008). This is a vulnerable period where infants are susceptible to impaired growth and development if nutrition is not managed appropriately (Ministry of Health, 2008; Pan American Health Organization, 2003).

Breastfeeding is well recognised for its benefits to health and is the most important energy and nutrient source in the first year of life (Ministry of Health, 2008; Pan American Health Organization, 2003). The current national nutrition guidelines advise infants to be exclusively breastfed until around six months of age (Ministry of Health, 2008; WHO, 2003). At this time an infant's stores of iron and zinc begin to deplete so appropriate foods need to be gradually included as breast milk alone can no longer meet

an infant's energy and nutritional requirements (Dewey, 2001; Ministry of Health, 2008; Pan American Health Organization, 2003). Between nine and eleven months of age, over 70% of iron, zinc, magnesium, sodium and calcium requirements need to be provided by complementary foods (Dewey, 2001). From twelve months of age, the complementary foods consumed are more likely to resemble the range of foods consumed by the family, and breast milk or formula typically contributes to only one-third of an infants' intake (Dewey, 2001). The introduction of cow's milk should be delayed until this time to avoid the risk of iron deficiency (Ministry of Health, 2008).

Currently there are no recommendations on the number of serves of complementary foods infants require each day. This is due to the wide variation in individual requirements as infants develop and hence the current recommendations emphasise growth, development and achieving a varied food intake (Ministry of Health, 2008). Given the relatively small amounts of complementary foods that are consumed by infants, it is important that food choices are nutrient dense, especially as eating patterns identified as early as nine months of age have been shown to continue throughout childhood (Lioret, McNaughton, Spence, Crawford, & Campbell, 2013; Pan American Health Organization, 2003). Early cessation of breastfeeding has been linked to inappropriately introduced complementary foods prior to four months of age, and food types that are considered inappropriate before one year of age such as cow's milk and snack foods high in sugar or salt (Ministry of Health, 2008; Morton et al., 2012; Soh et al., 2002). Early introduction of complementary foods (before 4 months of age) is associated with an increased risk of iron deficiency, malnutrition, food allergies, vulnerability to infections and eczema (American Academy of Pediatrics, 2012; Government of Canada, 2012; Ministry of Health, 2008). Late introduction of complementary foods (after 6 months of age) also increases the risk of iron deficiency, micronutrient deficiencies as well as faltering growth (McKean, 2017; Ministry of Health, 2008; National Health and Medical Research Council, 2012).

There are only a few studies that have described food and nutrient intake in infants. Most studies assessing dietary intakes in infants and toddlers (0-24 months) have used weighed or estimated food records, multiple 24-hour recalls (24HR) or food frequency

questionnaires (FFQ) (Conn, Davies, Walker, & Moore, 2009; Devaney, Ziegler, Pac, Karwe, & Barr, 2004; Emmett, North, & Noble, 2007; Fisher et al., 2008; Lioret et al., 2013; Sharma et al., 2013; Soh et al., 2002). In Australia, the poor quality of some diets during the complementary period have been documented as early as nine months of age (Conn et al., 2009; Lioret et al., 2013). The early cessation of breastfeeding (prior to nine months) has been linked with low iron and zinc intakes (Conn et al., 2009). In contrast, infants that are still breastfed at nine months, have been shown to have greater diet diversity compared with infants not receiving breast milk, and are less likely to consume nutrient-displacing drinks such as juice or cordial (Conn et al., 2009).

There are also concerns about the timing and quality of complementary foods in NZ infants diets. A cross-sectional survey using weighed food records and serum biomarkers in NZ found 15% of infants and 66% of toddlers were at risk of inadequate iron intakes (Soh et al., 2002). One of the biggest longitudinal study's conducted in NZ, the Growing up in New Zealand Study, assessed dietary intake in 9-month old infants using a computer assisted telephone interview (non-validated questionnaire) which highlighted concerns with the diets of NZ infants (Morton et al., 2012). They found three in four infants ceased exclusive breastfeeding and were introduced to infant formula or milk by four months of age (Morton et al., 2012). Cow's milk had been consumed as a drink by 5.4% of infants, despite the national guidelines recommending cow's milk be delayed until infants are at least 12 months to avoid the risk of iron deficiency (Ministry of Health, 2008; Morton et al., 2012). Therefore, dietary assessment alongside measures of growth and development, could help identify potential nutritional problems and provide an opportunity for intervention earlier in life.

There are many challenges involved with dietary assessment in children under 12 months of age. These include rapid dietary changes as infants transition from milk to complementary foods resulting in day to day variation in intake, difficulties in quantifying intake as food is often spilled or wasted and the heavy burden on the parents who have to report intake (Ortiz-Andrellucchi et al., 2009). This creates issues with estimating portion size, and hence energy intake is often overestimated in infants (Andersen, Lande, Arsky, & Trygg, 2003). It can also be difficult to quantify nutrient

intake within a short timeframe, as infant's diets get progressively more diverse as they transition through complementary feeding. Breast milk provides over half of an infant's total energy intake once they start on complementary foods, and this creates an additional challenge in dietary assessment, as breast milk intake is difficult to quantify (Dewey, 2001).

Assessing usual dietary intake is essential to determine the adequacy of the diets of both individuals and the population, and is useful in guiding and optimising nutrient intake. There are many dietary assessment methods available, but differences lie in the accuracy of the data collected, the ability of the population to complete them and the time and resources needed. Traditionally food records have been used, a prospective method which collects detail of food and beverage intake over a period of time. This method places a large burden on the participant, requires multiple days of data collection, as well as effort to analyse and interpret the findings. Food records are therefore time-consuming in large population groups (Willett & Lenart, 2013).

Shorter dietary assessment methods that help assess adherence to nutrition guidelines could be useful tools in both the clinical and research setting. These methods could identify those that would benefit from further nutritional support but need to be valid, reliable and specific to the population they are being used in (Cade, Thompson, Burley, & Warm, 2002). Food frequency questionnaires (FFQ) are commonly used as they can gather data from large groups of participants without the time, burden or expense that food records pose (Willett & Lenart, 2013). Food frequency questionnaires are retrospective methods that can be useful in categorising and grouping high or low intakes as well as identifying those at upper or lower extremes of intake (Willett et al., 1985). Different age-groups and cultures have different dietary patterns and food preferences. It is important that FFQs are current and specific to the population of interest so that their results can be interpreted with confidence (Cade et al., 2002; Metcalf, Swinburn, Scragg, & Dryson, 1997; Willett & Lenart, 2013).

Generally, FFQs have been focused on the adult population with emerging research expanding to children and toddler populations. These tools have been developed or

modified specifically for this younger population group. In infants this involves adjusting portion sizes to assess the small amounts of foods consumed, considering milk intake (both breast milk and infant formula) and the types of foods specific to this population (puree and baby foods). Newly developed or modified tools must be re-validated to ensure they are measuring what they claim to measure. Validation of a dietary assessment method requires that it be compared with a superior and preferably independent technique, although there is no 'gold-standard' for this. The majority of research in children 12-36 months tends to use 24-hour diet recalls (24HR) and weighed food records for this (Lovell, Bulloch, Wall, & Grant, 2017) due to the ability of these tools to quantify nutrient intake (Cade et al., 2002; Willett & Lenart, 2013). There are very few FFQs that have been validated for nutrient intake in infants less than 12 months of age (Andersen et al., 2003; Gondolf, Tetens, Hills, Michaelsen, & Trolle, 2012; Marriott et al., 2008; Palacios et al., 2017) and none of these are specific to NZ infants.

1.2 Purpose of the study

The purpose of this study is to validate a short dietary assessment tool that assesses the complementary food intake in infants. Having a tool that can evaluate diet adequacy and quality in infants would be beneficial in studies monitoring intake over time. It may be particularly useful where a simple tool is needed with little participant burden to compare groups of infants who are progressing with complementary foods, including identification of unhealthy early dietary practices and to investigate the impact of interventions aimed at improving early growth and nutrition. There are currently no validated dietary assessment methods available to assess nutrient intake in NZ infants less than 12 months of age.

1.3 Aim

The aim of this research is to determine the relative validity and reproducibility of a complementary food frequency questionnaire (CFFQ) that can be used in future research to assess nutrient intake in NZ infants aged 9 to 12 months. The primary objective is to validate the CFFQ against a reference method of a four-day weighed food

record (4dWFR) for nutrient intake of NZ infants aged 9 to 12 months. The secondary objective is to assess the reproducibility of the CFFQ by having participants complete the CFFQ on two separate occasions, four weeks apart. We hypothesise that the CFFQ will be a valid method, producing reasonable agreement to the 4dWFR for energy and nutrient intake. We also hypothesise that the CFFQ will be a reliable method, showing adequate agreement between both CFFQ administrations.

1.4 Thesis structure

Chapter one, the introduction, presents the purpose of the research leading to the aims and objectives, and justification for the study. Chapter two reviews the literature on infant feeding patterns, dietary assessment methods and challenges of assessing dietary intake in infants (including the development and evaluation of tools to assess dietary intake). Chapter three is a complete presentation of the validation and reproducibility research study, presented as a manuscript for publication. Finally, chapter four includes the conclusions of this study and how they relate to the knowledge within this field as well as recommendations for future research. Supplementary appendices include the questionnaires and food records used in the study and additional supplementary results not included in the manuscript.

1.5 Researcher's contributions

Table 1.1 Contribution of each researcher to the completion of the study.

Researcher	Role and contributions to thesis
Amy Judd	MSc student – Nutrition and Dietetics **Contribution:** Primary Researcher: Participant recruitment, data collection, data entry and analysis, statistical analysis and formulation of results and writing of thesis and manuscript.
Dr Cath Conlon	Senior Lecturer, School of Sport, Exercise and Nutrition

	Expert in maternal, infant and paediatric nutrition including breast milk composition and infant feeding. **Contribution:** Primary Academic Supervisor: Provided research concept, assisted with ethical approval, guidance of research design and development of methods, supervised with progression of the research process through to final manuscript.
Dr Kathryn Beck	Senior Lecturer, School of Sport, Exercise and Nutrition *Expert in dietary assessment and the development and validation of dietary assessment tools.* **Contribution:** Academic Co-supervisor: Assisted with statistical analysis and formulation of results, thesis revision and guidance to produce final manuscript.
Dr Christopher McKinlay	Neonatologist, Kidz First Neonatal Care, Counties Manukau Health Senior Lecturer, Liggins Institute and Department of Paediatrics: Child and Youth Health, University of Auckland *Expert in maternal and perinatal health as well as developmental origins of health and disease.* **Contribution:** Co-supervisor: Revised final thesis and provided guidance to help produce final manuscript.

Chapter 2. Literature review

2.1 Introduction

Relevant literature was identified by searching online databases (Web of Science, PubMed and Google Scholar) and manually searching reference lists of original articles for key papers. The search terms used in the search:

- infant, e.g., infant, newborn*, babies, baby,
- diet, e.g., nutrition, food intake, infant nutrition, nutritional assessment, complementary feeding,
- dietary assessment, e.g., questionnaire*, dietary assess*,
- dietary assessment tool, e.g., food frequency questionnaire, FFQ, 24-hour recall, 24HR,
- validation, e.g. validity, reproducibility, reliability, repeatability.

Key words and combinations were identified in free text, article titles and abstracts, and were used to perform a comprehensive search of the databases. All relevant retrieved articles were sent to EndNote® (version X7.8; Thomson Reuters). The search focused on relevant studies published before June 2018 and was limited to those published in English. This review of the literature explores dietary assessment methods in infancy and the challenges specific to this population group as well as considerations when assessing the validity and reproducibility of dietary assessment tools and scope for their use in practice.

2.2 Nutrition during infancy

Nutrition during infancy is fundamental to growth and development. Infants have rapidly changing physiological requirements and nutritional needs relative to the remainder of their lifecycle, hence nutrient intake and growth can impact health in later life (Geleijnse et al., 1997; Karlsson, Ahlborg, & Karlsson, 2005; Owen, Martin, Whincup, Smith, & Cook, 2006; Riordan, 2005). Rapid early weight gain, early cessation of breastfeeding and high protein intakes have all been shown to influence adiposity and cardiovascular health in later life (Baird et al., 2005; Barker et al., 2005; Günther et al., 2007; Koletzko et al., 2009; Owen et al., 2005).

Infants transition from a diet of exclusive milk intake (breast milk and/or infant formula) to a more diversified diet that matches the family patterns by late infancy (12 months of age). The current New Zealand (NZ) Food and Nutrition Guidelines for Healthy Infants and Toddlers advise exclusive breastfeeding of infants until around six months of age, as milk (either breast milk or infant formula) is the most important energy and nutrient source in the first year of life (Ministry of Health, 2008). From six months of age, breast milk alone can no longer meet an infant's nutritional requirements as their stores of iron and zinc are depleted and breast milk is relatively low in these and other minerals (Dewey, 2001; Ministry of Health, 2008). At this time or when an infant indicates they are ready, but no sooner than four months of age, appropriate foods need to be gradually introduced to complement breast milk intake (Ministry of Health, 2008).

From nine months of age, a wider range and larger quantity of complementary foods are accepted that contribute significantly more to the diet than seen initially at six months, as breast milk and formula intake are reduced (Ministry of Health, 2008; Morton et al., 2012). Between nine and eleven months of age most of the requirements for iron, zinc, magnesium, sodium and calcium need to be provided by complementary foods (Dewey, 2001). Eating patterns as early as nine months of age have been shown to continue throughout childhood (Lioret et al., 2013; Pan American Health Organization, 2003). This means poor dietary patterns such as consuming energy-dense, nutrient poor foods in infanthood could be continued throughout the rest of childhood. As infants only consume relatively small amounts of complementary foods at this stage, it is vital that food choices are nutrient dense. From twelve months of age, the complementary foods consumed more closely meet the range of foods consumed by the family and breast milk or formula intake usually only makes up a third of an infant's dietary intake. Cow's milk is not recommended as a drink before this time as it can increase the risk of depleted iron stores (Ministry of Health, 2008).

There are few studies that have assessed food and nutrient intake in infants. Studies from Australia have indicated the poor quality of some infants diets which include the

consumption of energy-dense, nutrient-poor foods from as early as nine months of age (Conn et al., 2009; Lioret et al., 2013). Early cessation of breastfeeding (prior to nine months) has been linked with low iron and zinc intakes (Conn et al., 2009). There are also concerns about the timing and quality of weaning diets in NZ infants, but a lack of current data exists. The Growing Up in New Zealand study (the largest longitudinal study which gives insight into child development in NZ) shows most infants (97%) had been breastfed at some stage (Morton et al., 2012). The median age infants ceased exclusive breastfeeding was at just four months of age (Morton et al., 2012). Less than 50% of the infants that had been breastfed, continued to be breastfed at nine months of age (Morton et al., 2012). As of 2017, only 52% of NZ infants were exclusively breastfed from birth, the lowest rate recorded in the last 10 years (Plunket NZ, 2018). Only 21% of NZ infants were exclusively breastfed by six months of age (Plunket NZ, 2018).

Early cessation of breastfeeding has been linked to the introduction of complementary foods that are considered inappropriate before one year of age (Ministry of Health, 2008; Morton et al., 2012; Soh et al., 2002). A small percentage of infants (5.4%) in the Growing Up in New Zealand cohort had been given cow's milk prior to 12 months of age (Morton et al., 2012). By nine months of age, NZ infants have generally been introduced to a wide range of solid foods, most commonly baby rice, or fruit and vegetables (Morton et al., 2012). Infants that are still breastfed at nine months, have more diet diversity compared with those who are not receiving breast milk and are less likely to consume nutrient-displacing drinks such as juice or cordial (Conn et al., 2009). Therefore, being able to identify potential nutritional problems in this transitional complementary feeding period could help provide an opportunity for appropriate interventions early in life.

2.3 Dietary assessment methods and challenges in infants

Dietary assessment remains a challenge across all ages and therefore various tools exist to assess dietary patterns and estimate food and nutrient intake. Dietary assessment in infants is essential for monitoring the nutrients needed for growth and development. Valid and reliable tools are needed to help our understanding of the dietary determinants of nutritional status (Kolodziejczyk, Merchant, & Norman, 2012). There is

no ‘gold standard’ for dietary assessment but weighed food record’s (WFR) and 24-hour recalls (24HR) are commonly used as they are generally more precise in quantifying nutrient intake (Cade et al., 2002; Willett & Lenart, 2013). Food frequency questionnaire’s (FFQ) can also be used to estimate nutrient intake and have an advantage of obtaining data from a large group over multiple days without the burden or expense of the WFR or 24HR (Willett & Lenart, 2013). This is an important consideration as dietary assessment can create substantial participant burden, especially in this age group, impacting both adherence and the ability to obtain accurate data (Watson et al., 2015).

Weighed or estimated food records, multiple 24HR or FFQs have been the main methods used by a small number of studies assessing dietary intake in infants and toddlers (0-24 months) (Conn et al., 2009; Devaney et al., 2004; Emmett et al., 2007; Fisher et al., 2008; Lioret et al., 2013; Sharma et al., 2013; Soh et al., 2002). Few studies have looked at assessing nutrient intake in the transitional period from milk to complementary feeding (6-12 months) (Andersen et al., 2003; Gondolf, Tetens, Hills, Michaelsen, & Trolle, 2012; Marriott et al., 2008; Palacios et al., 2017). Dietary assessment in infants is a complex task, as it relies on the parent or guardian to accurately record dietary intake despite not all foods offered to the infant being consumed but rather spilled or wasted. This is further complicated by the nature of infant dietary habits that are rapidly changing, and the fact many children have multiple carers (including childcare facilities) responsible for their food intake (Ortiz-Andrellucchi et al., 2009; Watson et al., 2015). It is likely due to these numerous challenges that only a few dietary assessment tools have been developed for use in infants.

2.3.1 Breastfeeding

Breast milk is a core energy source for most infants generally providing half of their total energy intake once started on complementary foods. One challenge of dietary assessment in infants is the ability to accurately quantify the volume of breast milk consumed. Large variation exists in breast milk composition between mothers, between days and between feeds (Ballard & Morrow, 2013). It is also difficult to quantify exactly

how much breast milk an infant consumes in a single feed. To address this, previous studies have excluded breastfed infants from their research or breastfed infants have only represented a small portion of the total cohort (Gondolf et al., 2012; Soh et al., 2002; Watson et al., 2015). However, as breastfeeding is the gold standard source of nutrition for infants, excluding breastfed infants does not provide a fair representation of the population and their nutrient intake.

Validated methods have been developed for estimating breast milk volume and have been used in various other studies to overcome part of this challenge (Devaney et al., 2004; Lanigan, Wells, Lawson, Cole, & Lucas, 2004; Lioret et al., 2013; Marriott et al., 2008; Paul, Black, Evans, Cole, & Whitehead, 1988). These methods are based on the average intake of breast milk in infants aged seven to twelve months of age, which is approximately 600 ml per day. Another interpretation of this is 100 ml of milk for a feed lasting ten minutes or longer, or a proportion of this if the feed is shorter in duration (10 ml per minute). These values are based on previous validated assumptions including those used by the Ministry of Health to establish the Nutrient Reference Values (NRV) in infants (Conn et al., 2009; Devaney et al., 2004; Dewey, 2001; Dewey, Finley, & Lonnerdal, 1984; Emmett et al., 2007; Paul et al., 1988; Sharma et al., 2013).

2.3.2 Estimating portion size

Dietary assessment relies on the ability to accurately depict food consumption and portion size. A range of different methods have been used in research for estimating portion size in infants and toddlers. These include using household measures (cups and tablespoons), portion size photographs, food models, commonly used sizes (e.g. 1 slice of bread) and using the child's hand as a guide (Lovell et al., 2017). In adolescents, estimating portion sizes appears to have some advantage over using specified pre-determined sizes, showing higher measurements of agreement and reliability (Tabacchi et al., 2013). However, energy intake is often overestimated in infants, which is likely attributed to the difficulty in parent's accurately estimating the portion of food their child has consumed, especially as infants and toddlers eat only very small amounts of foods and tend not to eat everything on their plate (Andersen et al., 2003; Lovell et al., 2017).

2.3.3 Plate wastage

Infants are prone to being messy eaters, especially as exploring food is a key part of development as they continue to learn and grow. This complicates dietary assessment as not all food served, is consumed and instead food is often chewed and spat out or spilt and leftover (Ortiz-Andrellucchi et al., 2009). Dietary assessment in this age group requires thorough measurement procedures to account for this. Over- or under-reporting is common in this age group as a result of plate or food wastage (Andersen et al., 2003). Plate waste may contribute considerably to dietary assessment error, so it is important to guide participants on the best practices to measure or estimate the food not consumed. Recording the amount of food offered and the amount eaten or wasted separately helps to encourage parents and caregivers to differentiate between the two, and likely improves the ability to estimate nutrient intake. This method was utilised in NZ studies with children aged 12 to 24 months, which found acceptable to good validity and high repeatability for a FFQ in terms of ranking nutrient intakes (Mills et al., 2015; Watson et al., 2015).

2.3.4 Dietary progression

Dietary assessment in infants is challenging as this is a period of rapid change, growth and development within a relatively short period of time (Gondolf et al., 2012). Teething in infants can further complicate dietary assessment as it can lead to irritability, disturbed sleep, drooling and loss of appetite (Watson et al., 2015). Infant's diets vary with age as they transition from breast milk and/or infant formula as a core food to including a variety of complementary foods. Initially new foods should be introduced one at a time to safely identify any allergens and allow the infant to explore different tastes and textures (Ministry of Health, 2008). Current guidelines in NZ (Ministry of Health, 2008) promote texture progression which occurs as foods go from purees to minced and then soft foods as the infant's teeth develop. Some mothers may follow baby-led weaning which involves first foods provided in a whole food form as finger food rather than puree form. There is not enough evidence yet to support this approach, so baby-led weaning is not currently supported by the NZ Ministry of Health (Ministry of Health, 2008). Either way, over time the diet becomes more diverse as a range of

different foods are introduced. These changes can make it difficult to quantify nutrient intake within a short timeframe, as certain foods and therefore nutrients may be eaten less often, and therefore not captured in dietary assessment. For this reason, using multiple, non-consecutive days of dietary assessment should improve the variety of foods captured in the diet assessment. Infants who have just transitioned onto complementary foods (around six months of age) have much less diverse diets than those from eight or nine months of age (Ministry of Health, 2008; Morton et al., 2012). Therefore, the age and stage of an infant needs to be considered when undertaking dietary assessment, as using the same tool in a wide range of ages could skew the results due to differences in diet diversity related to each stage of development.

2.3.5 Multiple caregivers

Dietary assessment in infants is reliant on a surrogate reporter such as a parent, caregiver and/or childcare teacher. This means the quality of the data can vary depending on the reliability of the person reporting the data, whether the data is recorded in the home or not, and what methods are used to obtain portion sizes (Livingstone & Robson, 2007). Also, the primary caregiver may not be solely responsible for providing the food and fluid intake for their infant and the responsibility may actually be shared with other adults including childcare teachers and family support (Ortiz-Andrellucchi et al., 2009). This can make dietary assessment difficult, as it can be hard to get the information needed when numerous carers are involved.

2.4 Food frequency questionnaires exploring dietary intake

Controversy exists around which dietary assessment tool is most appropriate for use in infants (Cade et al., 2002). Simple and short dietary assessment tools such as 24HR, FFQ and other innovative tools are associated with reduced participant burden, data handling and processing costs (Bell, Golley, & Magarey, 2013). Food frequency questionnaires (FFQ) are commonly used to assess dietary intake (Bell et al., 2013) and estimate dietary intake over a specified period of time. They are a relatively inexpensive method to obtain data from a large group of people and are fairly easy to complete meaning they lessen the participant burden and data handling compared to other

methods (Andersen et al., 2003; Bell et al., 2013; Willett & Lenart, 2013). Food frequency questionnaires have been found to be a valid and useful tool for assessing energy and nutrient intake in children of various ages (Andersen et al., 2003; Blum et al., 1999; Marriott et al., 2008; Preston, Palacios, Rodriguez, & Velez-Rodriguez, 2011; Watson et al., 2015) but have the tendency to overestimate energy intake (Livingstone & Robson, 2007; Watson et al., 2015). With this overestimation in mind, it has been suggested that FFQs might not be appropriate for measuring absolute nutrient intake despite many providing acceptable to good validity and good reproducibility (Andersen et al., 2003; Blum et al., 1999; Marriott et al., 2009; Palacios et al., 2017; Watson et al., 2015). However, FFQs have been the primary method used to assess micronutrient intakes in children (Ortiz-Andrellucchi et al., 2009). Food frequency questionnaires have been shown to be valid and reproducible tools in children as young as one year of age, generating adequate estimates of some vitamins and minerals (Lovell et al., 2017). Many different types of FFQs exist, each with different formats but there are a lack of high-quality, short dietary intake tools available for children less than 12 months of age (Bell et al., 2013). Having validated dietary assessment tools specifically for exploring dietary intake in infants is particularly important due to the diversity and variation in infant diets.

2.5 Food frequency questionnaires available for use in New Zealand infants

At least four tools have been validated in infants 12 months or less, but these are not specific to the NZ population (Andersen et al., 2003; Gondolf et al., 2012; Marriott et al., 2009; Marriott et al., 2008; Palacios et al., 2017) (see summary in Table 2.1). The infant feeding questionnaire validated for use in the United Kingdom by Marriott et al (2009) has been modified for the NZ population and validated for nutrient intake and dietary patterns in NZ toddlers (Mills et al., 2015; Watson et al., 2015). This tool has low rates of misclassification and therefore has been found to be an acceptable tool for ranking a child's nutrient intake as well as helping to identify children with extremes of dietary intake (Watson et al., 2015). However, this dietary tool was designed as a face-to-face interview and has not been validated in younger infants, so cannot be used for reliable dietary assessment in NZ infants less than twelve months of age

Table 2.1 Summary of tools and characteristics of validation studies in infants (n=5).									
Reference, country	*Sample size, age assessed*	*No. food items*	*FFQ Type*	*Administration method*	*Consumption interval*	*Reference method, interval*	*Statistical methods used*	*Relevant results (validity)*	*Nutrients assessed and other notes*
Andersen et al., 2003; Norway	64, 12m	144	Semi-quantitative	Self-administered (parent)	Previous 14d	7dWFR, 1-2 weeks following FFQ	Spearman rank correlation, cross-classification (quartiles), Bland-Altman Adjusted for energy intake	Median nutrient intakes significantly higher, except calcium (p>0.05) r= 0.50 (range 0.18 (Vit D)-0.72 (PUFA)) *energy adjusted:* r= 0.50 (range 0.16 (Vit D)-0.79 (iron) Same quartile, 38% (range 22% (fibre)-56% (SFA)); opposite quartile,3%	Nutrients: energy, macronutrients, fibre, Vit A, Vit D, Vit E, Vit C, Vit B_1, Vit B_2, calcium, iron Breastmilk estimated from frequency and duration
Gondolf et al., 2012; Denmark	36, 9m	NA	Pre-coded food record (PFR)	Self-administered (parent)	Previous 7d	7dWFR, 7-10 days following PFR Also with TEE using DLW technique	T-test on differences, Bland-Altman	Mean nutrient intake similar (overestimated by PFR) except significantly lower for protein (p<0.01)	Nutrients: energy, macronutrients (including added sugar) Excluded breastfed infants
Marriott et al., 2008; United Kingdom	50, 6m	34	Quantitative	Interviewer-administered	Previous 7d	4dWFR, 7-15 days following FFQ	Spearman rank correlation, Bland-Altman Adjusted for energy intake	Median nutrient intake significantly higher, except sodium (p>0.05) r=0.63 (range 0.39 (fat)-0.86 (Vit D) *energy adjusted*: range r=0.55 (copper)-0.89 (Vit B_1)	Nutrients: energy, macronutrients, sodium, potassium, calcium, magnesium, phosphorus, iron, zinc, copper, Vit A, Vit D, Vit E, Vit B_1, Vit B_2, Vit B_3, Vit B_{12}, Vit B_6, folate, Vit C Breastmilk estimated from frequency and duration

Marriott et al., 2009; United Kingdom	50, 12m	78	Semi-quantitative	Interviewer-administered	Previous 28d	4dWFR, 4-10 days following FFQ	Spearman rank correlation, Bland-Altman Adjusted for energy intake	Mean nutrient intakes significantly higher in FFQ, apart from Vitamin E (p=0.08) r= 0.49 (range 0.25 (Vit E)-0.66 (sodium)) *energy adjusted:* r=0.48 (range 0.24 (Vit B_{12})-0.75(sodium))	Nutrients: energy, macronutrients, sodium, potassium, calcium, magnesium, phosphorus, iron, zinc, copper, Vit A, Vit D, Vit E, Vit B_1, Vit B_2, Vit B_3, Vit B_{12}, Vit B_6, folate, Vit C Breastmilk estimated from frequency and duration
Palacios et al., 2017; Puerto Rico	241, 0-24m	52	Semi-quantitative	Interviewer-administered	Previous 7d	Multiple 24HR (x2), 1 week apart (weeks 2 and 4)	Spearman rank correlation, cross-classification (quartiles) Adjusted for energy intake	Median nutrient intakes higher in FFQ r=0.49 (range 0.24 (copper)-0.73 (energy)) *energy adjusted:* r=0.53 (range 0.26 (folate)- 0.77 (energy)) Correctly classified, 83% and gross misclassification, 17%	Nutrients: energy, macronutrients (including SFA, MUFA, PUFA, omega-3), fibre, Vit A, Vit D, Vit E, Vit K, Vit C, Vit B_1, Vit B_2, Vit B_3, Vit B_5, Vit B_6, folate, Vit B_{12}, calcium, phosphorus, magnesium, iron, zinc, copper, potassium Breastmilk estimated from frequency and duration Also analysed data excluding breast milk and formula FFQ repeated at week 3 (reproducibility)
Abbreviations: 24HR, twenty-four hour recall; 4dWFR, four day weighed food record; 7dWFR, seven day weighed food record; d, day; DLW, doubly labelled water; FFQ, food frequency questionnaire; m, month; MUFA, monounsaturated fat; PUFA, polyunsaturated fat; SFA, saturated fat; TEE, total energy expenditure.									

2.6 Considerations when assessing the validity and reproducibility of a food frequency questionnaire

Before a questionnaire is used in research or clinical practice, it needs to be validated in a group of representative subjects of the study population (Preston et al., 2011). Validation of a dietary intake questionnaire checks it is measuring what it should measure. Results from studies using validated FFQs can be interpreted with greater confidence (Masson et al., 2003). In conducting a validation study, the measures from a FFQ are compared with an alternative but not necessarily more accurate method of assessing diet. This assesses the *relative* validity, as the alternative dietary assessment method has its own limitations (Masson et al., 2003). There are many factors that affect the validity of a dietary assessment tool including the population characteristics, study design, reference method and sequence of administration (Cade et al., 2002; Lovell et al., 2017).

2.6.1 Population characteristics

Food frequency questionnaires should not be used in countries or age-groups they are not specified for (Cade et al., 2002). Cultural diversity in food patterns exist across different countries and some foods (and particularly drinks) are consumed by infants and toddlers that are not consumed by adult populations. This would mean many foods could be missed if the FFQ was not tailored for the specific group it was going to be used in. In adults and children, age, ethnicity, sex and health status can affect the outcome of a validation study (Cade et al., 2002; Preston et al., 2011). For this reason, it is essential to ensure the population in which the FFQ is validated is similar to the study population and participants that could skew the data (such as those children with allergies or who were born premature) are excluded from analysis.

Very few FFQs have been validated for use in infants outside of European populations (Bell et al., 2013; Cade et al., 2002). A NZ study assessing food group intake in Māori, Pacific and other children 1-14 years, found correlations between a FFQ and food record were generally lower in Pacific children than in other children. It also found higher correlations in those 1 to 4 years of age than older children (Metcalf et al., 2003).

Therefore, it is necessary to consider the impact of demographic information when exploring dietary trends. There are currently no validated dietary assessment methods that are relevant for infants less than 12 months of age in the NZ population.

2.6.2 Questionnaire design and administration method

There are many aspects of FFQ design that impact on validity including the number of items in the questionnaire, the administration method, the choices of foods included and quality of pre-testing (Lovell et al., 2017). If a questionnaire is too long it risks not obtaining all the accurate information as the participant burden increases. If the questionnaire is too short, it may not gather enough information to obtain meaningful results. Also, if the foods included are not relevant to the age group in question, the data obtained may be meaningless.

Questionnaires can be led by an interviewer or self-administered depending on the needs of the study. Interviewers themselves can add a level of error or bias into the survey process (Cade et al., 2002). Self-administered questionnaires require careful preparation and pre-testing to ensure questions are communicated effectively to gather all the relevant information (Cade et al., 2002). A self-administered questionnaire is less burdensome for the participant as it gives more flexibility to complete it, on a day and time that suits them, rather than relying on an agreed time of an interviewer (Ocke et al., 2015). It also allows a wider reach, as more questionnaires can be administered to participants to complete at their own pace, without the interviewer having to arrange separate times with each one. Self-administered questionnaires however, require a literate and motivated population to complete them. Utilising technology to deliver questionnaires helps to increase the efficiency in data collection and extends access, as participants can use their smartphone, laptop or computer device. This can simplify data collection, making it less logistically challenging for the researcher and allow rapid dissemination of results to those that need it. However, there tends to be an improvement in correlation coefficients in validation studies when a FFQ is interviewer-administered compared to self-administered in both children and adults which is an important consideration with all studies with infants relying on a parent or proxy-reporter (Cade et al., 2002; Lovell et al., 2017).

2.6.3 Assessing nutrient intake: food composition databases

An extensive and comprehensive database is needed to convert food intake data into nutrient values (Cade et al., 2002). Software needs to incorporate data relevant to the participant population. Although there are some foods similar to that consumed in adults, infants usually consume a range of commercial and homemade baby foods and/or infant formulas that children and adults do not typically consume. It is important that software can incorporate these foods to ensure accurate assessment of nutrient intake is possible. The NZ Food Composition Data 2016 was released in 2017 and is jointly owned by Plant and Food Research and the Ministry of Health in New Zealand who manage and maintain the database. It provides a comprehensive collection of high-quality nutrient data specific to NZ foods and therefore reliable nutrient values for foods commonly consumed in NZ (New Zealand Institute for Plant & Research, 2018). This database also contains information on various baby foods and formulas consumed in New Zealand. FoodWorks 9 (Xyris 2018) uses this database to analyse dietary intake data. This software also allows for foods to be created and modified based on similar products or recipes, which is well suited to the infant population.

2.6.4 Reference method: biomarkers vs. weighed records

There is no 'gold standard' for directly assessing the validity of a FFQ (Cade et al., 2002; Preston et al., 2011). The doubly labelled water technique is the gold standard for measuring total energy expenditure and has been widely used in infants (Butte et al., 2000; Gondolf et al., 2012). This method as well as the collection of plasma or urine to test for dietary biomarkers enables objective assessment of dietary intake without the bias associated with self-reported dietary intakes and is therefore less prone to errors (Hedrick et al., 2012). Although there are now good biomarkers to assess energy, protein and sodium intake, there still remains no ideal method for measuring dietary intake as a whole (Cade et al., 2002). It is also generally unsuitable to collect plasma or urine to test for biomarkers in infants, as these procedures are often expensive, invasive, and only validate one nutrient at a time, which makes them inefficient for use in validation studies looking at multiple nutrients (Cade et al., 2002; Lanigan et al., 2004). For this

reason, the relative validity of a FFQ is often compared with another dietary assessment method.

Weighed food records (WFR) have long been recognized as the most precise method available for estimating usual dietary intakes (Gibson, 2005; Gondolf et al., 2012). They are subject to more bias compared to the doubly labelled water technique for energy intake (Lanigan et al., 2004). However, they have the least correlated errors and hence have been recommended as the first method of choice when validating FFQs (Andersen et al., 2003; Cade et al., 2002). In infants less than one year of age, weighed records have been shown to be the best technique for assessing dietary intake (Burrows, Martin, & Collins, 2010; Luque et al., 2013; Potischman, Cohen, & Picciano, 2006). In toddlers (aged 12-24 months), weighed records have presented better correlations for several micronutrients than other methods (e.g. estimated food records or 24HR), which is likely due to portions being weighed rather than estimated (Lovell et al., 2017; Ortiz-Andrellucchi et al., 2009). However, a limitation to WFRs are the burden they place on those completing them, particularly if they are complex and require many days.

Twenty-four hour diet recalls (24HR) are less demanding for the participant and less likely to influence the actual diet of the subjects compared to WFRs. However the sources of error for 24HR tend to be more associated with the errors in a FFQ such as a reliance on memory, conceptualisation of portion sizes and distortion of reported diet. This makes it a less robust reference method in a validation study (Cade et al., 2002). Data from 24HRs have also overestimated intakes of infants and toddlers compared to WFR (Fisher et al., 2008) and have not been precise enough at the individual level (Livingstone & Robson, 2007). A recent systematic review of toddler dietary assessment tools found when 24HRs were repeated two to three times over non-consecutive days they could provide a more reliable estimate of nutrient intakes in young children with good agreement to a FFQ (Lovell et al., 2017).

2.6.5 Sample size and number of recording days

Validation studies need an adequate number of participants to produce robust results. Close to 100 subjects has been suggested as an adequate size for a FFQ validation study

(Willett & Lenart, 2013). This helps to ensure the sample accurately represents the target population (i.e. has similar characteristics). When comparing nutrient intake, it is also important to minimise the standard error of the means. This can be achieved by either increasing the number of subjects or increasing the number of days recorded (Nelson, Black, Morris, & Cole, 1989). In adults, when food records are kept for two weeks or more, validity statistics require a minimum of 50, and ideally more than 100 participants (Cade et al., 2002). For correlation coefficients, the sample size depends on the expected association between the two measures, requiring approximately 150 participants (Cade et al., 2002).

Long periods of recording are necessary to achieve accurate dietary intake information to establish nutrient intake. A key issue with long periods of recording however, is the high rate of participant drop out and unusable records and associated retention bias. As infant diets rapidly change within a short period of time, diet records need to be kept for a sufficient number of days to give adequate representation of nutrient intake. Non-consecutive days are more appropriate to estimate the prevalence of inadequate intake as they provide a better representation of the variation of the usual diet (Ocke et al., 2015). The number of days needed to measure nutrient intake in groups of individuals is influenced by the within-person to between-person variation ratio (Lanigan et al., 2004). The smaller the ratio, the fewer the days of recording needed. In infancy, variability in food intake is usually greater between-individuals than within-individuals. This is because dietary needs are usually met in a fairly uniform way with a limited number of complementary foods and a substantial amount of energy supplied by breast milk (Lanigan et al., 2004; Nelson et al., 1989).

Nelson et al (1989) determined that seven days is adequate to determine most nutrient intakes in a range of age groups, although, fewer days were needed for children less than four years of age compared with older children and adults. Seven-day food records are generally adequate for most nutrients except copper and vitamin E which require ten days of records, retinol which requires eleven days, vitamin B_{12} which requires twelve days and beta-carotene which requires at least twenty days of records (Nelson et al., 1989). A more recent review of dietary assessment methods also found seven

days of records adequate for ranking children for energy intake and most nutrients, but vitamin intake was variable and often required up to twenty days of records (Livingstone & Robson, 2007). However, recording food records for this long is very burdensome, and not feasible in infants, as most caregivers would not commit to undertaking even seven days of WFR (Livingstone & Robson, 2007). Having fewer recording days (five days or less) reduces the respondent burden associated with completing a WFR, and enhances the accuracy of the records, as parents are likely to lose interest for extended periods of recording (Conn et al., 2009; Lanigan et al., 2004; O'Connor et al., 2001; Stram et al., 1995).

A recent systematic review on feeding tools for children aged 12-36 months of age found most food records varied in length from three to seven days (Lovell et al., 2017). Previous validity studies using a FFQ in NZ toddlers (Mills et al., 2015; Watson et al., 2015), included five days of records as the reference for validity. Five days of records has been shown to be an acceptable number of days to determine nutrient intakes (energy, protein, fat, carbohydrate and micronutrients such as calcium, iron, zinc, and vitamin C) in young infants in the United Kingdom and capture as many days as possible whilst minimising the participant burden (Lanigan et al., 2004). Marriot et al (2008, 2009) used four days as this was consistent with other trials and was adequate to classify 75% of infants into the correct quintile of intake (Boggio, Grossiord, Guyon, Fuchs, & Fantino, 1999; Harbottle & Duggan, 1993; Lanigan, Wells, Lawson, & Lucas, 2001). A review by Cade et al (2002) and earlier calculations by Stram et al (1995) agreed in that the optimal study design will rarely require more than four days of diet records per participant.

The reference method in infants should ideally incorporate intake over the same number of days used in the FFQ so they can effectively measure the same foods and therefore nutrients (Marriott et al., 2009). If differences exist there could be significant change in dietary patterns recorded by one method, which would therefore skew the data. This is particularly relevant in infants as they have rapid development and changing diet over this transition from milk to complementary foods.

2.6.6 Sequence of administration

It is important to consider the sequence of administration in a validation study to optimise the results and reduce errors. Ideally the FFQ should be administered prior to the reference measure as this would mimic how participants would normally encounter it, independent of any other dietary assessment measure (Cade et al., 2002). Administering the FFQ first provides a chance to gather information on the respondents diet prior to the WFR and avoid any bias as a result of increased awareness of their diet, related to the effort of weighing and recording food consumption with this activity. Hence, if the FFQ was completed after the WFR, the accuracy would increase. However a disadvantage to administering the FFQ first is that it covers a different period of dietary assessment and hence lower associations could be found between records. To reduce this, the FFQ could be administered both before and after completion of the reference method (Willett & Lenart, 2013).

Reproducibility or reliability involves administering a questionnaire at two points in time to the same people and assessing the association between responses (Cade et al., 2002). It refers to the consistency of data obtained in more than one administration of the same instrument to the same participants at different times. The interval between repeat measurements should be chosen to minimise changes over time and recall of previous answers, and will depend on the reference period of the questionnaire (Cade et al., 2002). If the questionnaires are re-administered too close together, participants may remember their previous responses, giving false measures of reproducibility (Metcalf et al., 2003). If re-administered too far apart there could be too much variation due to real life dietary changes, and therefore reduced reliability, as infants diets are rapidly changing over this time (Bell et al., 2013).

A 2002 review assessing the development of FFQs found correlations were higher for questionnaires administered a month or less apart (Cade et al., 2002). Intervals between test and re-test vary between studies, but are generally between two weeks to one month (Blum et al., 1999; Mills et al., 2015; Palacios et al., 2017; Watson et al., 2015). The validation studies in NZ toddlers used a four-week period between administrations of the questionnaires (Mills et al., 2015; Watson et al., 2015).

2.7 Statistical analysis of a dietary assessment tool for validity and reproducibility

2.7.1 Assessing and interpreting validity and reproducibility

Validity and reproducibility have been tested using a mixture of statistical methods as there is no 'gold-standard' to assess this (Willett & Lenart, 2013). Paired t-test's (or Wilcoxon's signed rank test for non-normally distributed data) can assess relative validity at the group level by comparing mean nutrient intake and assessing the mean percent difference between two dietary assessment methods (Gibson, 2005). Paired t-test's however, do not provide information on the agreement at the individual level or on the quality of the questionnaire. The effect size is often calculated to obtain an objective measure of the magnitude of the observed effect between the methods. This is calculated using the following equation: effect size $r = \sqrt{t^2}/ (t^2 + df)$ (where t= the test statistic produced by the paired t-test and df = the degrees of freedom) (Field, 2013). An effect size of ≥0.5 has been used to indicate a large effect, 0.3 a medium effect and 0.1 a small effect (Field, 2013).

Correlation coefficients

Correlation coefficients are used in the majority of dietary assessment tool evaluation studies (Altman & Bland, 1983; Bell et al., 2013). A 2002 review assessing the development of FFQs found 90% of studies used correlations for assessing reproducibility (Cade et al., 2002). Correlation coefficients assess the strength and direction of the association between two different methods (Bland & Altman, 1986; Cade et al., 2002; Lombard, Steyn, Charlton, & Senekal, 2015). Pearson's correlations are used for normally distributed data, whereas Spearman's correlations are used for non-normally distributed data. There are a number of different ways to interpret correlations but when assessing FFQs, it has been suggested that correlation coefficients greater than 0.50 indicate 'good' associations, 0.20 to 0.49 show 'acceptable' associations and any coefficients less than 0.20 indicate 'poor' associations (Masson et al., 2003). When establishing test-retest reliability of a method, acceptable intra-class correlations ranged from 0.4 to 0.7 in a recent systematic review of FFQ tools for use in children (Lovell et al., 2017).

The use of correlations alone to assess validity however is debated, as correlations do not measure the agreement between methods (Bland & Altman, 1986; Lombard et al., 2015). Bland and Altman (1986) argue that when assessing two methods that measure the same thing (i.e. nutrient intake), a positive correlation will always exist. Also, a high correlation can exist despite methods having poor agreement. Correlation coefficients are affected by the agreement of the reference data, mode of administration, age, sex and ethnicity of the study population (Preston et al., 2011). Correlations can also be impacted by sample size, with a larger sample resulting in lower correlations (Cade et al., 2002). Correlations on their own may be inappropriate when assessing validity, but they may be more useful when used alongside other statistical techniques, and as a way to compare results with other studies (Bland & Altman, 1999; Cade et al., 2002; Masson et al., 2003).

Cross-classification and weighted kappa statistic

Cross-classification can be used to help validate dietary assessment methods by showing to what extent each method can rank participants correctly. This involves classifying participants for each method into quantiles (tertiles, quartiles or quintiles) and then calculating the percentage of participants who are correctly classified into the same category by both dietary methods along with the percentage of participants misclassified into opposite categories, by the two dietary methods. This helps to establish the proportion of subjects that have been correctly classified (and misclassified) into high or low percentiles of the distribution of nutrient intake (Nelson et al., 1989). However, this method includes participants who might have been correctly classified by chance alone. To account for both the percentage of correctly classified participants and the expected proportion of participants classified by chance alone, the weighted-kappa (κ) statistic can be used (Masson et al., 2003). The κ statistic does not consider the degree of disagreement between methods but instead treats it all equally as total disagreement (Masson et al., 2003). The κ statistic can be used to interpret the level of agreement between methods where if the methods agree completely $\kappa=1$ and if they disagree entirely $\kappa=0$. Therefore, a value ≥ 0.61 indicates good agreement, between 0.20 to 0.60 acceptable agreement, and <0.20 poor agreement (Lombard et al., 2015; Masson et al., 2003).

Bland-Altman analysis

Bland-Altman analysis has been commonly used in validation studies to assess the agreement between methods for nutrient intake (Andersen et al., 2003; Bell et al., 2013; Davies, Coward, Gregory, White, & Mills, 1994; O'Connor et al., 2001; Watson et al., 2015). Unlike cross-classification, Bland-Altman analysis reflects the level of agreement while also reflecting the direction and extent of any bias (Masson et al., 2003). The difference between the two methods is plotted against the mean of the two measures for each participant. It is strongly recommended to use 95% limits of agreement (LOA) to compare methods (Bland & Altman, 1999; Cade et al., 2002) The LOA are calculated of the normal distribution and reflect over and underestimation of estimates (calculated as the mean difference ± 1.96 SD). The purpose of the analysis is to assess agreement between the methods as well as reflect any changes with increasing nutrient intake.

Adjustments for energy intake

Many validation studies that have assessed energy intake, have adjusted for energy intake, as nutrient intake is positively correlated with energy intake (Andersen et al., 2003; Blum et al., 1999; Marriott et al., 2009; Marriott et al., 2008; Preston et al., 2011). Energy adjustment has strong implications for correlation coefficients and can make it difficult to compare results to other studies that have not adjusted for energy intake (Lovell et al., 2017). In toddlers, energy-adjustment created higher correlation coefficients compared to crude values (Lovell et al., 2017). In infants, improvements in validity between dietary assessment methods have been found following energy adjustment (Andersen et al., 2003; Marriott et al., 2008).

2.8 Summary

This review of the literature has highlighted the challenges of dietary assessment in infants and the importance of having validated short dietary assessment tools specific to the infant population. The weighed food record is the gold standard dietary assessment reference method in validation studies and requires several non-consecutive days to gather enough data to establish nutrient and energy intake. Both the tool and the reference method should assess a similar number of days and ideally

be administered within a month. To assess validity and reproducibility, a variety of statistical methods are needed to assess associations and agreement between methods including correlation coefficients, cross-classification, weighted Kappa and Bland-Altman analysis.

Chapter 3. Research manuscript: Determining the Relative Validity and Reproducibility of a Complementary Food Frequency Questionnaire to Assess Nutrient Intake in New Zealand Infants aged 9 to 12 months

3.1 Abstract

Background: Dietary assessment in infants is challenging but necessary to understand the relationship between nutrition and growth and development. However, there are currently no simple, validated dietary assessment methods that assess nutrient intake in New Zealand infants.

Objective: To assess the relative validity and reproducibility of a complementary food frequency questionnaire (CFFQ) to determine nutrient intakes of New Zealand infants aged 9 to 12 months.

Methods: A cross-sectional study design was used. Ninety-five parent-infant pairs (infant age 10 ± 1 months) completed the CFFQ twice (CFFQ-1 and CFFQ-2), approximately 4 weeks apart (to assess CFFQ reproducibility). A four-day weighed food record (4dWFR) was collected on non-consecutive days between CFFQ administrations (to assess CFFQ validity). Validity and reproducibility were assessed for intakes of energy and 18 nutrients using paired t-tests, Pearson's correlation coefficients, cross-classification using tertiles, weighted Kappa and Bland-Altman analysis.

Results: Nutrient intakes from the CFFQ were comparable to the 4dWFR, with correlation coefficients ranging from r=0.18 for saturated fat to r=0.81 for iron (mean r=0.52). For most nutrients there was good cross-classification between the CFFQ and 4dWFR (>50% correctly classified and <10% grossly misclassified). On average, 54% (mean) of participants were correctly classified (range 39% to 67%). Between 2.1% and 14.7% of participants (mean 7.1%) were misclassified into opposite tertiles. For most nutrients there was acceptable agreement between the CFFQ and 4dWFR (κ=0.20–0.60). The CFFQ showed good short-term reproducibility: for all nutrients correlation between administrations was r≥0.20, good cross-classification apart from fat and saturated fat (41% and 47%, respectively) and all nutrients had less than 10% of participants grossly misclassified. All nutrients showed acceptable to good agreement (κ>0.20).

Conclusion: The CFFQ appears to have acceptable validity and good reproducibility for assessing nutrient intake in infants aged 9-12 months, making it a useful tool for use in future research.

Keywords: infant, dietary assessment, reliability, validation, questionnaire, nutrient

3.2 Introduction

Rates of obesity are increasing in New Zealand (NZ), effecting a third of adults and one in eight children (Ministry of Health, 2017). Dietary intake in infancy, rapid early weight gain and early cessation of breastfeeding have all been shown to influence adiposity in later life (Baird et al., 2005; Barker et al., 2005; Günther et al., 2007; Koletzko et al., 2009; Owen et al., 2005). Dietary intake in infants is highly transitional, changing at around six months of age from a diet consisting entirely of breast milk and/or infant formula to one consisting of a variety of foods by twelve months. Infants are nutritionally vulnerable during this complementary feeding period, as milk alone can no longer meet an infant's dietary requirements (particularly energy, iron and zinc) and if not completed appropriately infants are at an increased risk of impaired growth and development (Ministry of Health, 2008; Pan American Health Organization, 2003).

There are concerns about the diets of NZ infants during the period of complementary feeding. For example, one study found that 15% of infants were at risk of inadequate iron intake (Soh et al., 2002) and in another study three in four infants had ceased exclusive breastfeeding prior to the six months recommended by national guidelines (Ministry of Health, 2008; Morton et al., 2012). Appropriate assessment of dietary intake in young children is important in furthering our understanding of the links between diet and growth and development, and could aid in evaluating the impact of any intervention strategies.

However, dietary assessment in children under 12 months of age is particularly challenging. Infants' diets get progressively more diverse as they transition from milk to solids resulting in wide variation in daily dietary intake. Many infants rely on breast milk intake which is difficult to quantify, and they also consume very small amounts of food making it difficult to estimate portion size and assess nutrient intake.

There are a lack of tools available to assess nutrient intake during the complementary period in infants, with debate regarding which method is most appropriate for use in this age group (Cade et al., 2002). Traditionally food records have been used to assess

dietary intake, however, they have a large participant burden, require multiple days of data collection, analysis is time consuming and interpretation is complicated. Therefore in large population studies, food records are usually replaced with food frequency questionnaires (FFQ), as they gather data without the time, burden or expense that food records pose (Willett & Lenart, 2013). Food frequency questionnaires categorise and group participants into high or low intakes (Willett et al., 1985) . As dietary patterns and food preferences vary across time and population groups, FFQs need to be current and specific to the population of interest so that their results can be interpreted with confidence (Cade et al., 2002; Metcalf et al., 1997; Willett & Lenart, 2013). Newly developed or modified tools must be validated to ensure they are measuring what they claim to measure, which requires comparison to a superior and preferably independent technique. Although many FFQs have been used in the adult population, there are very few FFQs that have been validated for assessment of nutrient intake in infants less than 12 months of age (Andersen et al., 2003; Gondolf et al., 2012; Marriott et al., 2009; Marriott et al., 2008; Palacios et al., 2017) and none are specific to NZ infants. Therefore, the purpose of this study was to determine the relative validity and reproducibility of a complementary food frequency questionnaire to assess nutrient intake in NZ infants at 9 to 12 months of age.

3.3 Methods

3.3.1 Study population

Participants were recruited from around New Zealand, over three years (2016-2018) through advertisements on social media and via email to community and parent groups. Participants were screened for eligibility through an emailed questionnaire prior to registering for the study. Eligible participants were the parent or main carer of an infant aged between 9 and 12 months. Participants were excluded if their baby had been born pre-term (<37 weeks) or had been diagnosed with an illness or received medications that could impact on growth or food consumption. Ethical approval was granted by the Massey University Human Ethics Committee, Auckland, New Zealand (NOR15/061). Prior to participation in this study, written informed consent was obtained from all caregivers on behalf of themselves and their child.

3.3.2 Study design

A cross-sectional study design was used to determine the validity and reproducibility of the CFFQ. Participants completed the CFFQ twice, four weeks apart to assess reproducibility. The CFFQ was delivered online and sociodemographic information was collected with the first administration (CFFQ-1), including infant age, length of gestation, sex, ethnicity, number of siblings, and the most recent height, weight and head circumference recorded in their Well Child book. After completion of the CFFQ-1, participants completed a weighed food record for four non-consecutive days (4dWFR) to assess validity. The CFFQ was then repeated (CFFQ-2) four weeks after the first administration to assess reproducibility.

3.3.3 Data collection

Complementary Food Frequency Questionnaire (CFFQ)

Development of the CFFQ was informed by the Growing Up in NZ Study (Morton et al., 2012) and national dietary guidelines for infants and toddlers (Ministry of Health, 2008). A list of foods relevant to infant dietary intake was created and prioritised based on the contextual and cultural appropriateness of each, before being assigned frequency and portion sizes to reflect typical intake in this age group. The final CFFQ comprised of 49 food items under 6 food categories: milk and fluid, cereals and carbohydrates, dairy products, meat and protein, miscellaneous foods, and vegetables and fruit. The CFFQ was reviewed by a registered dietitian and pretested in a small group of caregivers for comprehension (not part of this validation study). The CFFQ was delivered as part of an infant feeding assessment tool, which contained four sections to collect information on growth (section 1), feeding history of both food and fluids (section 2 and 3) as well as assess current food and fluid intake (section 4). The CFFQ was incorporated into section 4, which collected information on the quantity and frequency of foods eaten in the previous four days (See Appendix A). Only section 4 (the CFFQ) was used in validity and reproducibility studies. Portion responses in the CFFQ were in teaspoons (tsp) and tablespoons (Tbsp) where possible to account for the very small portion sizes consumed in infants. Breastfeeding duration and frequency were recorded and breast milk volume estimated using previously validated calculations based on milk composition during late lactation (7-20 months) (Dewey et al., 1984). For infants aged 9 to 12 months, the

average intake of breast milk was estimated at 600 ml per day or 100 ml of milk for a feed lasting 10 minutes or longer. For feed times less than 10 minutes, a proportion of this (i.e. 10 ml per minute) was calculated.

4-day Weighed Food Record (4dWFR)

The 4dWFR was emailed or posted out to each participant, with instructions and examples of how it should be completed (See Appendix B). The primary caregiver was instructed to only commence the 4dWFR once the CFFQ-1 had been completed. Caregivers were advised to account for the child's entire dietary intake over a 24-hour period, including any feeds at night or early in the morning. All foods and fluids were to be weighed and recorded on four non-consecutive days including at least one weekend day. Participants were able to use their own household electronic scales to weigh food and fluids. If participants did not have a scale, a Tablefair White Electronic Scale was sent out to them. Instructions were included on how to use food scales, including how to tare and reweigh food for this study.

Participants were requested not to change the foods and fluids given to their child whilst completing the food diary. Participants were asked to include the time of the meal or snack, the name and brand (if relevant) of the food or drink as well as the cooking method (where appropriate). The weight of each food or drink was recorded before being offered to the child, and then any leftover (or spilt) food or drink was reweighed and recorded. A guide on how to estimate portions of food and drinks where a weight was not possible was also included, which involved household measures, using the infants palm as a reference measure or a proportion of a package with a known weight. Participants were also asked to record recipes for foods they prepared and served to their infants. This included the amount of each ingredient added, the cooking method and the proportion of the recipe served to the child. Participants were asked to record the name, brand and dose of any supplements their infant was taking. For formula-fed infants, participants were instructed to weigh the dry powder and the volume of water used before reweighing the final quantity. For breastfed infants, the duration and frequency of suckling was recorded which was later used to estimate the volume of milk consumed.

3.3.4 Data handling

Nutrient intake was assessed by extracting the CFFQ survey data from Survey Monkey into an Excel spreadsheet (Microsoft Office Corporation, 2011). All data were checked to ensure there were no missing data, and to ensure a full 4dWFR had been completed, before analysis and inclusion in the validation study. Both the CFFQ-1 and CFFQ-2 needed to be complete for inclusion in the reproducibility study. Data from the CFFQ was analysed for nutrient content in FoodWorks 9 (Xyris Software, 2018), which utilises the NZ Food Composition Database (NZ, FOODfiles 2016). The nutrients of interest were: energy, protein, total fat, saturated fat, carbohydrate, fibre, vitamin E, folate, potassium, calcium, zinc, selenium, thiamin, riboflavin, niacin, vitamin C, vitamin B_{12}, iodine and iron. Two data sets were created for each 4dWFR and CFFQ, one that included milk intake (breast milk and formula) and one that excluded milk intake. This was done to explore the impact of the estimation of milk intake on CFFQ validity.

Once the 4dWFRs were checked, participants were contacted to obtain any missing details, such as portion sizes, brands or descriptions of foods. This ensured the records were of high quality and that accurate nutritional information was entered into FoodWorks 9 (Xyris Software, 2018) for nutrient analysis. Food records and output nutrient data were checked for any unusual values that could indicate input error or implausible records. If specific foods or brands were not located in the NZ Food Composition Database on FoodWorks 9 (Xyris Software, 2018), the product was created using the nutrition information panel (NIP) of the product. For micronutrients not found on the NIP, similar products were found in Australian or other NZ food databases and the nutrition profile was based on these foods. All recipes were entered using cooked ingredients where possible. If a recipe was not available or a parent was unsure of the recipe (e.g. if the food had been prepared before the start of the study), a similar product was chosen in the NZ Food Composition Database. Only three infants were receiving a nutritional supplement, which were identified as a prebiotic, so supplement intake was not included in analysis.

3.3.5 Statistical analysis

Statistical analysis was undertaken using IBM SPSS 23.0 (Chicago, IL, 2015). Data were checked for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests and the null hypothesis (i.e. that the test distribution was similar to the normal distribution) was rejected with a *p* value <0.05. Normality was also assessed visually using histogram plots. Nutrients that appeared non-normally distributed were logarithmically transformed for analysis. Categorical variables were reported as numbers and percentages. Descriptive statistics of continuous variables were reported as means and standard deviations (SD) for normally distributed data. Geometric means and 95% confidence intervals (CI) were used for log-transformed data. Data were analysed with and without milk (breast milk and formula) included. Energy-adjusted nutrient intakes were calculated as the residuals from the regression of nutrient intake on energy (Willett et al., 1985).

Validity of the CFFQ-1 compared to the 4dWFR was assessed by three general methods. First, daily nutrient intakes derived from the CFFQ and 4dWFR were compared using paired t-tests, with a *p* value <0.05 considered to represent a statistically significant difference. Differences were quantified by effect size, calculated using the following equation: effect size $r = \sqrt{t^2/(t^2 + df)}$ (where t= test statistic produced by paired t-test and df= degrees of freedom). An effect size of ≥0.5 was considered large effect, 0.3 medium and 0.1 small (Field, 2013). Differences were also presented as percentage difference.

Second, the strength of linear association between the CFFQ-1 and 4dWFR for nutrient intake was assessed by Pearson correlation coefficient. A coefficient ≥0.50 was interpreted as 'good' association, 0.20-0.49 as 'acceptable' and <0.20 as 'poor' (Masson et al., 2003).

Third, agreement between methods assessed by cross-tabulating by tertiles, and the percentage of participants correctly classified into the same tertile or grossly misclassified into opposite tertiles was calculated. Agreement was deemed adequate if correct classification into the same tertile occurred for >50% of participants and gross misclassification into opposite tertiles occurred for <10% of participants (Masson et al.,

2003). The degree of agreement was further quantified with the weighted kappa (κ) statistic (Cohen, 1968). The formula used to determine the κ-statistic was: κ = Pr(a) – Pr(e) / 1 – Pr(e) where Pr(a) is the relative observed agreement among the dietary assessment methods, and Pr(e) is the hypothetical probability of chance agreement. A weighting of one was used for participants classified into the same third by each dietary assessment method; 0.5 for adjacent thirds; and zero for opposite thirds. If the two dietary methods completely agree then κ = 1, and if there's no agreement between the two methods other than that expected by chance (Pr(e)) then κ = 0. Masson et al. (2003) criteria was used as a measure of agreement; values of kappa ≥0.61 indicating good agreement, between 0.60 and 0.20 acceptable agreement and <0.20 poor agreement (Lombard et al., 2015; Masson et al., 2003).

The degree of agreement between the CFFQ-1 and 4dWFR was further assessed using Bland-Altman analysis (Bland & Altman, 1999). The difference in nutrient intake between the two methods was plotted against the average of the two dietary methods. Only the mean differences that were not statistically different (p>0.05) were included in Bland-Altman analysis. The 95% limits of agreement were calculated as the mean difference ± 1.96 SD. To investigate bias, linear regression analysis was undertaken, with the difference in intake the dependent variable, and the mean intake the independent variable.

Reproducibility of the CFFQ was assessed by comparing and relating nutrient intakes from the CFFQ-1 and CFFQ-2 using the same methods described above.

3.4 Results

3.4.1 Participant characteristics

A total of 95 parent-child pairs completed both the 4dWFR and the CFFQ-1 and were included in the validity analysis. Ninety-three parent-child pairs completed both the CFFQ-1 and the CFFQ-2 and were included in the reproducibility analysis (Figure 3.4.1). The characteristics of the participants are outlined in Table 3.1. In almost all cases, the participant was the mother of the child (98.8%). Half of the infants were female (50.6%), the majority were of NZ European ethnicity (82.4%), and the mean ± SD age was 10 ± 1 months and mean ± SD weight was 8.79 ± 1.29 kg. Nearly three quarters of the infants had been breastfed at some stage (72.6%) and the mean ± SD age for starting solids was 5.5 ± 0.6 months. Most infants were offered solids before milk at the time of the study (70.5%).

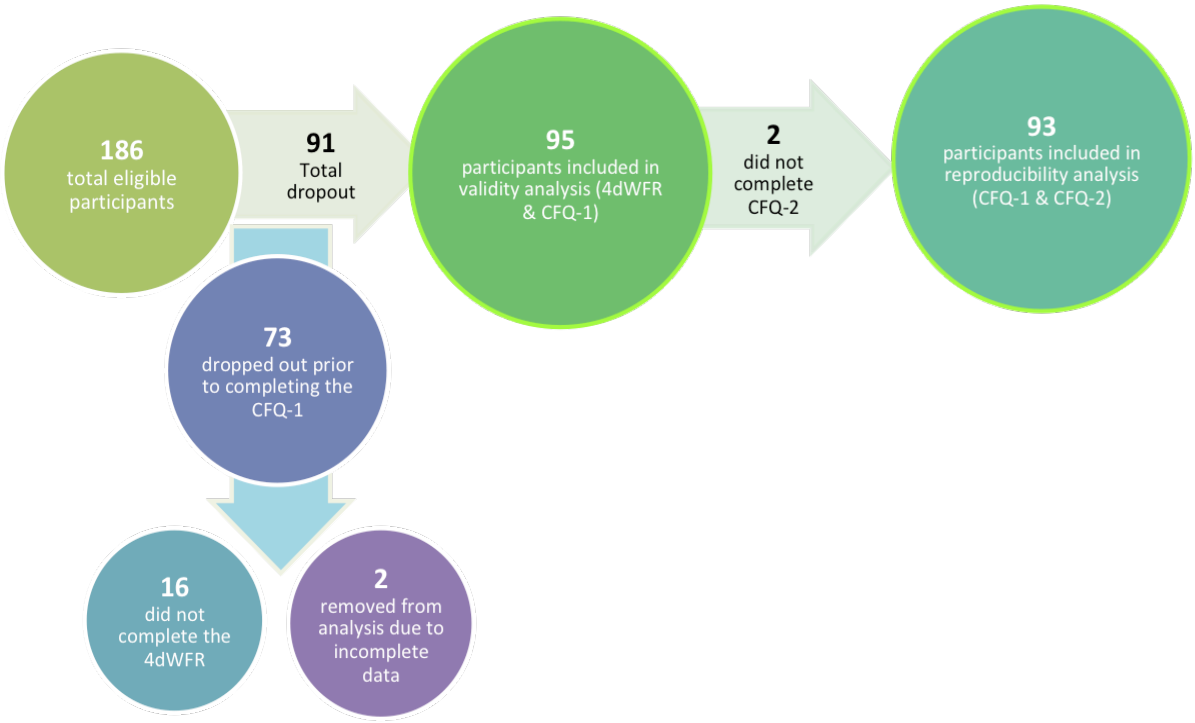

Figure 3.4.1 Participant flow diagram

Table 3.1 Participant characteristics.

Characteristics	Study Participants [a] *(n=95)* *Mean ± SD or n (%)*
Age (month)	10 ± 1
Weight (kg)	8.79 ± 1.20
Sex of infant [b]	
Female	43 (50.6)
Caregiver completing CFFQ [b]	
Mother	84 (98.8)
Father	1 (1.2)
Length of gestation (week)	39 ± 2
Ethnicity of infant [b] [c]	
NZEO	70 (82.4)
Asian	7 (8.2)
Māori	4 (4.7)
Pacific	1 (1.2)
Indian	2 (2.4)
Other	1 (1.2)
Family status [b]	
Only child	45 (52.9)
One sibling	28 (32.9)
Two or more siblings	12 (14.1)
Breastfed at any stage	
Yes	69 (72.6)
Age started solids (months)	5.5 ± 0.6
Milk or solids	
Milk first	28 (29.5)
Solids first	67 (70.5)
Special diet [d]	
Yes	19 (20.0)

[a]Study participants are those who completed at least one CFFQ and the four-day weighed food record (93 participants completed the first and second CFFQ only); [b]10 participants missing data; [c] Self-selected *main* ethnicity. Other ethnicity is Czech; [d]Special diet includes vegetarian or gluten-free/dairy-free diets

Abbreviations: NZEO - New Zealand European; CFFQ - Complementary food frequency questionnaire.

3.4.2 Validity of the Complementary Food Frequency Questionnaire (CFFQ)

Paired t-test and correlation coefficients

Energy and nutrient intakes for the 4dWFR and CFFQ-1 are presented in Table 3.2. The mean difference between intakes recorded by the CFFQ-1 and 4dWFR ranged from <1% to 26.6%. The CFFQ-1 produced significantly higher nutrient intakes for fat and saturated fat, but significantly lower nutrient intakes for carbohydrate, fibre, folate, potassium, thiamin, riboflavin, niacin and vitamin C (all $p<0.01$). With the exception of the large effect size for fibre ($r=0.5$), a medium effect size ($r=0.3$) was observed for the remaining nutrients.

The mean difference between the two methods increased when milk was excluded from analysis, range 2.2% to 36.5%; and the CFFQ-1 no longer produced significantly higher nutrient levels for fat and saturated fat ($p>0.05$). Energy, vitamin E, calcium, selenium, iodine and iron were also significantly lower by the CFFQ-1 when milk was excluded from analysis (all $p<0.05$). A large effect size ($r=0.5$) was observed for potassium, niacin and iodine, a small effect size ($r=0.1$) for energy, vitamin E and calcium and a medium effect size ($r=0.3$) for the remaining nutrients (carbohydrate, fibre, folate, selenium, thiamin, riboflavin and iron). After adjusting the crude data (including milk intake) for energy intake (Supplementary Table 1), nutrients were not statistically different between the 4dWFR and CFFQ-1.

Pearson correlation coefficients ranged from 0.18 (saturated fat) to 0.81 (iron), with a mean correlation of 0.52. All of the nutrients showed significant correlations ($p<0.05$) except for saturated fat ($p=0.07$). A good correlation ($r\geq0.50$) was found for protein, potassium, calcium, zinc, thiamin, riboflavin, niacin, vitamin C, vitamin B_{12}, iodine and iron. An acceptable correlation (r=0.20–0.49) was found for energy, fat, carbohydrate, fibre, vitamin E, folate and selenium. The association between the methods was weakened when milk intake was excluded from analysis, range 0.21 (vitamin E) to 0.60 (niacin) with an average correlation of 0.44. All the nutrients showed significant correlations ($p<0.05$). When milk was excluded, saturated fat showed a good correlation (r=0.59; $p<0.01$) and potassium, zinc, riboflavin, vitamin C and vitamin B_{12} all changed from having good correlations ($r\geq0.50$) to acceptable correlations (r=0.20-0.49). When

adjusted for energy intake, the 4dWFR and CFFQ-1 correlation coefficients ranged from 0.24 (fibre) to 0.78 (calcium and iron) with a mean correlation of 0.52. Folate changed from having an acceptable correlation (unadjusted) to a good correlation with the energy-adjusted data (r=0.46 and r=0.57, respectively) and vitamin C moved from a good to acceptable correlation with energy-adjusted data (r=0.54 and r=0.44, respectively).

Table 3.2 Mean daily nutrient intakes over four days and correlations between the 4dWFR and CFFQ-1 among infants aged 9-12 months (n=95).

Nutrients	*Milk included* [b]						*Milk not included* [c]					
	4dWFR Daily intake[a]	*CFFQ-1 Daily intake*[a]	*Mean difference (%)*[d]	*Paired t-test (p-value)*	*Effect size*	*Correlation Coefficients* [e]	*4dWFR Daily intake*[a]	*CFFQ-1 Daily intake*[a]	*Mean difference (%)*[d]	*Paired t-test (p-value)*	*Effect size*	*Correlation Coefficients* [e]
Energy (kJ)	3295 ± 810	3306 ± 1047	<1	0.92	_	0.37†	1853 ± 720	1658 ± 774	-10.6	0.02	0.2	0.40†
Protein (g)	26.6 ± 8.8	27.2 ± 10.3	2.2	0.55	_	0.51†	18.9 ± 8.4	18.3 ± 9.8	-2.8	0.56	_	0.56†
Fat (g)	33.2 ± 8.7	37.1 ± 13.6	11.8	<0.01	0.3	0.35†	14.2 ± 7.2	15.2 ± 8.8	7.5	0.25	_	0.38†
Saturated fat (g)	13.5 ± 4.6	16.3 ± 6.2	20.5	<0.01	0.4	0.18	4.6 [3.9 - 5.4]	4.7 [3.8 - 5.7]	2.2	0.87	_	0.59†
Carbohydrate (g)	92.7 ± 31.2	83.6 ± 29.6	-9.8	<0.01	0.3	0.41†	57.0 ± 28.3	43.2 ± 24.0	-24.3	<0.01	0.4	0.39†
Fibre (g)	9.3 ± 4.5	6.8 ± 3.6	-26.6	<0.01	0.5	0.37†	8.5 ± 3.7	6.6 ± 3.6	-21.8	<0.01	0.4	0.41†
Vitamin E (mg)	4.8 ± 2.2	4.7 ± 2.4	<1	0.97	_	0.47†	2.3 ± 1.2	2.0 ± 1.3	-14.4	0.04	0.2	0.21*
Folate (µg)	137.8 ± 74.7	115.1 ± 54.2	-16.5	<0.01	0.3	0.46†	120.8 ± 75.2	96.2 ± 52.6	-20.4	<0.01	0.3	0.48†
Potassium (mg)	1257 ± 405	1071 ± 434	-14.8	<0.01	0.4	0.50†	910 ± 384	674 ± 366	-25.9	<0.01	0.5	0.49†
Calcium (mg)	478 ± 207	498 ± 246	4.1	0.27	_	0.73†	217 ± 120	190 ± 123	-12.1	0.03	0.2	0.55†
Zinc (mg)	4.8 ± 1.9	5.1 ± 2.3	5.8	0.13	_	0.67†	2.6 ± 1.2	2.5 ± 1.3	-6.7	0.20	_	0.45†
Selenium (µg)	23.8 ± 7.8	22.8 ± 8.1	-4.5	0.28	_	0.27†	13.8 ± 7.5	11.2 ± 7.1	-18.9	<0.01	0.3	0.40†
Thiamin (mg)	0.6 [0.6 - 0.7]	0.6 [0.5 - 0.6]	<1	0.01	0.3	0.69†	0.4 [0.4 - 0.5]	0.3 [0.3 - 0.3]	-25.0	<0.01	0.4	0.55†
Riboflavin (mg)	0.8 [0.7 - 0.9]	0.7 [0.6 - 0.8]	-12.5	<0.01	0.3	0.70†	0.5 [0.4 - 0.5]	0.4 [0.3 - 0.4]	-20.0	<0.01	0.4	0.42†
Niacin (mg)	5.5 [5.0 - 6.0]	4.7 [4.3 - 5.2]	-14.5	<0.01	0.4	0.66†	3.8 [3.4 - 4.2]	2.7 [2.4 - 3.0]	-28.9	<0.01	0.6	0.60†
Vitamin C (mg)	57.3 [51.8 - 63.4]	49.7 [44.8 - 55.1]	-13.3	<0.01	0.3	0.54†	29.0 [25.1 - 33.5]	18.6 [16.2 - 21.5]	-35.9	<0.01	0.5	0.35†
Vitamin B_{12} (µg)	1.0 [0.9 - 1.2]	1.0 [0.8 - 1.1]	<1	0.31	_	0.71†	0.7 [0.6 - 0.8]	0.6 [0.5 - 0.7]	-14.3	0.15	_	0.36†
Iodine (µg)	41.9 [37.4 - 46.9]	39.5 [34.5 - 45.3]	-5.7	0.20	_	0.76†	13.7 [11.7 - 15.9]	8.7 [7.2 - 10.5]	-36.5	<0.01	0.5	0.53†
Iron (mg)	4.6 [4.0 - 5.2]	4.3 [3.8 - 5.0]	-6.5	0.21	_	0.81†	3.0 [2.7 - 3.4]	2.5 [2.2 - 2.8]	-16.7	<0.01	0.4	0.59†

4dWFR, four-day weighed food record; CFFQ-1, First complementary food frequency questionnaire. [a] mean ± SD or geometric mean [95% CI]; [b] Unadjusted raw dietary data with milk (breast milk and formula) intake included; [c] Excludes milk (breast milk and formula) from analysis; [d] Mean difference calculated as CFFQ1-4dWFR/4dWFR, [e]Pearson's Correlation Coefficients; † p=<0.01, significant difference (2-tailed); * p=<0.05, significant difference (2-tailed). Effect size: ≥0.5, large; 0.3, medium; 0.1 small effect (Field, 2013).

Cross-classification and weighted kappa

At least 50% of infants were correctly classified into the same third of intake for 14 nutrients (protein, fat, carbohydrate, vitamin E, folate, calcium, zinc, thiamin, riboflavin, niacin, vitamin C, vitamin B_{12}, iodine and iron). Less than 10% were grossly misclassified into the opposite third of intake for 14 nutrients (as above but includes fibre and potassium rather than fat and folate). For all nutrients, a mean of 53.9% of participants had the same category classification by both the 4dWFR and the CFFQ-1 (range 39.0% for selenium to 67.4% for iron; Table 3.3). Between 2.1% (iron and calcium) and 14.7% (saturated fat) of participants (mean 7.1%) were misclassified.

Most of the nutrients showed acceptable agreement between the 4dWFR and the CFFQ-1 (κ=0.20-0.60). Saturated fat and selenium showed poor agreement (κ<0.20) and iron showed good agreement (κ>0.60).

When excluding milk from analysis, there were some minor changes indicating less agreement in methods. On average, half of participants (mean 50.3%) were correctly classified (range 42.1% for vitamin C to 60.0% for protein), whereas 9.2% of participants on average were grossly misclassified (range 6.3% for calcium and iron to 12.6% for energy and vitamin E). Energy and saturated fat both had good cross-classification (>50% correctly classified) and fat, carbohydrate, vitamin C and vitamin B_{12} no longer had good cross-classification (<50% correctly classified). Fat, saturated fat and folate had low misclassification with milk excluded (<10% grossly misclassified) but fibre, vitamin E and thiamin had higher levels of misclassification compared to milk included (>10% grossly misclassified). All nutrients showed acceptable agreement when milk intake was excluded (κ=0.20-0.60).

Table 3.3 Cross-classification by tertiles of nutrient intakes and weighted kappa based on the 4dWFR and CFFQ-1 among infants aged 9-12 months (n=95).

	Milk included [(b)]			*Milk not included* [(c)]		
Nutrients	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*
Energy (kJ)	44.2	10.5	0.25	50.5	12.6	0.30
Protein (g)	52.6	5.3	0.41	60.0	8.4	0.45
Fat (g)	52.6	10.5	0.34	45.3	9.5	0.27
Saturated fat (g)*	43.2	14.7	0.19	50.5	8.4	0.34
Carbohydrate (g)	55.8	9.5	0.39	46.3	8.4	0.30
Fibre (g)	46.3	9.5	0.29	44.2	10.5	0.25
Vitamin E (mg)	49.5	8.4	0.34	49.5	12.6	0.29
Folate (µg)	50.5	12.6	0.30	54.7	8.4	0.40
Potassium (mg)	45.3	8.4	0.29	48.4	7.4	0.34
Calcium (mg)	65.3	2.1	0.58	52.6	6.3	0.39
Zinc (mg)	60.0	4.2	0.50	54.7	9.5	0.38
Selenium (µg)*	39.0	12.6	0.17	47.4	11.6	0.27
Thiamin (mg)	57.9	3.2	0.49	51.6	11.6	0.32
Riboflavin (mg)	54.7	4.2	0.44	54.7	9.5	0.38
Niacin (mg)	57.9	3.2	0.49	57.9	8.4	0.43
Vitamin C (mg)	60.0	5.3	0.49	42.1	9.5	0.25
Vitamin B_{12} (µg)	61.1	4.2	0.52	43.2	7.4	0.27
Iodine (µg)	60.0	4.2	0.51	50.5	8.4	0.34
Iron (mg)	67.4	2.1	0.61	51.6	6.3	0.38

4dWFR, four-day weighed food record; CFFQ-1, First complementary food frequency questionnaire. [(b)] Unadjusted raw dietary data with milk (breast milk and formula) intake included; [(c)] Excludes milk (breast milk and formula) from analysis; *Not significant $p>0.05$ (Pearson chi-square, 2-sided).

Note: Participants were in tertiles, 2 groups of 32 and 1 group of 31 participants

When adjusted for energy intake, the CFFQ-1 showed comparable if not better agreement with the 4dWFR with 56.2% (mean) of participants correctly classified (range 39.0% (fibre) to 68.4% (iron)) and 6.8% grossly misclassified (range 1.1% (iodine) to 13.7% (selenium); Supplementary Table 2). Potassium showed good cross-classification compared to the non-adjusted data however vitamin E no longer showed good agreement (<50% correctly classified). Fat, saturated fat and folate had fewer

participants grossly misclassified compared to the non-energy adjusted data; but both carbohydrate and fibre no longer showed good agreement (>10% grossly misclassified). All nutrients showed acceptable agreement when adjusted for energy intake (κ=0.20-0.60) aside from fibre, which showed poor agreement (κ<0.20) and iron which like the unadjusted data, showed good agreement (κ>0.60).

Bland-Altman analysis

Bland-Altman plots were constructed to assess the level of agreement between the 4dWFR and CFFQ-1, and reflect the direction and extent of bias, as well as to identify any outliers present (Supplementary Figures 1-2). Examples of some of these plots are shown in Figure 3.4.2 and Figure 3.4.3 with a solid line representing the mean difference (or bias) between the two dietary assessment methods and dashed lines representing the limits of agreement. The mean bias appears a suitable representation of the differences between methods for all nutrients. Linear regression demonstrated differences were significantly dependent on the mean intake for energy, calcium, zinc and iodine ($p \leq 0.05$) (Supplementary Table 3). Protein, vitamin E, selenium and vitamin B_{12} showed no proportional bias meaning the 4dWFR and CFFQ-1 agree equally throughout the range of measurements ($p \geq 0.05$).

When milk intake was excluded, differences were significantly dependent on the mean intake for total fat and saturated fat ($p \leq 0.05$), whereas protein, zinc and vitamin B_{12} showed no proportional bias (Supplementary Table 4). When adjusted for energy intake, no proportional bias was present for any of the nutrients ($p \geq 0.05$), indicating the methods agree equally throughout the range of measurements (Supplementary Figure 3).

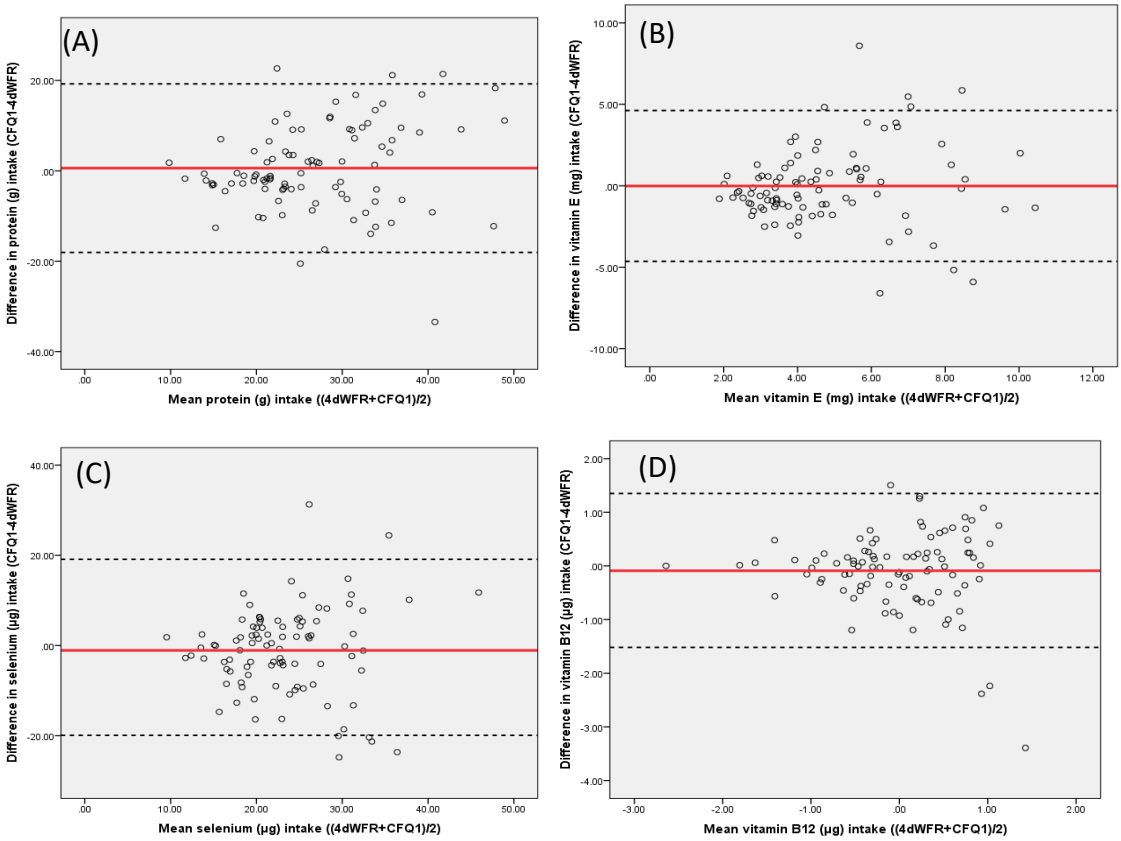

Figure 3.4.2 Example of Bland-Altman plots of the agreement between intakes for nutrients for (A) protein, (B) vitamin E, (C) selenium, and (D) vitamin B_{12} (n=95).

A solid line representing the mean difference between the two dietary methods and dashed lines representing the limits of agreement (LOA = mean difference ± 1.96 SD).

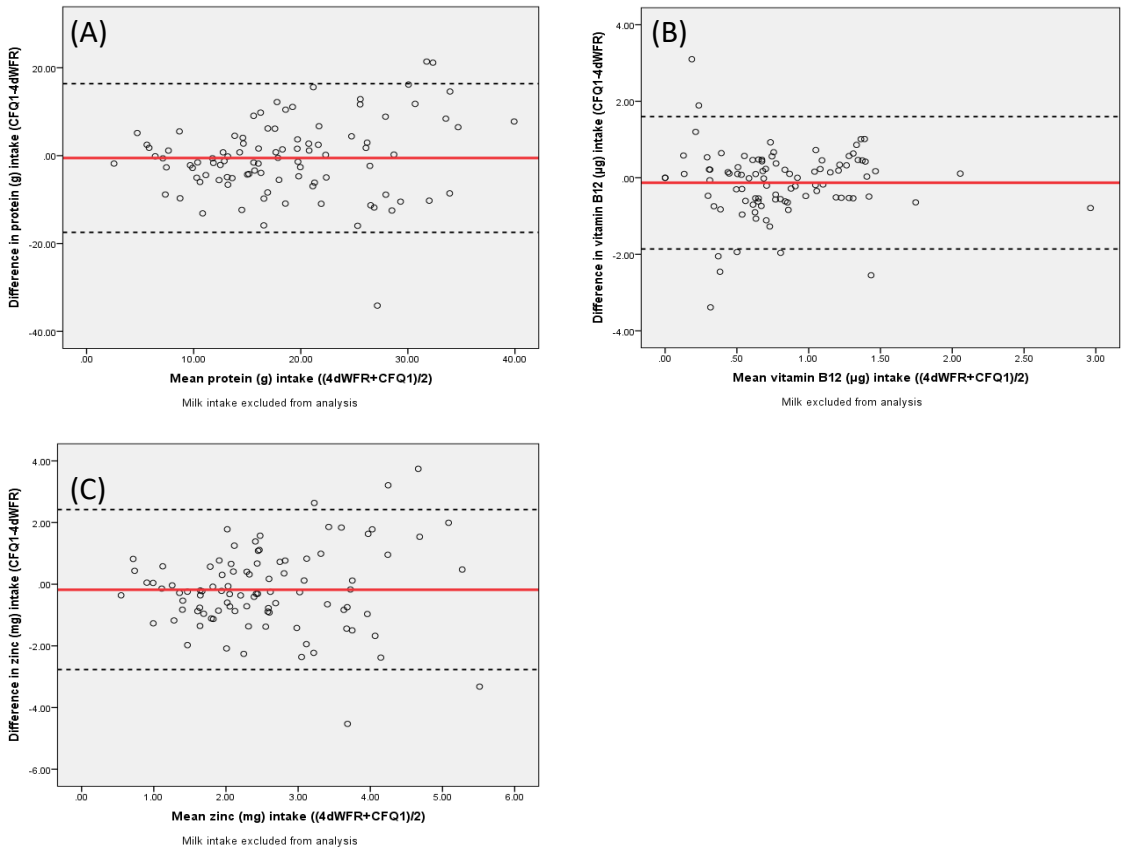

Figure 3.4.3 Examples of Bland-Altman plots of the agreement between intakes for nutrients for (A) protein, (B) vitamin B_{12} and (C) zinc, excluding milk (breast milk and formula) intake from analysis) (n=95).

A solid line representing the mean difference between the two dietary methods and dashed lines representing the limits of agreement (LOA = mean difference ± 1.96 SD).

3.4.3 Reproducibility of the Complementary Food Frequency Questionnaire (CFFQ)

Paired t-test and correlation coefficients

Energy and nutrient intakes for the CFFQ-1 and CFFQ-2 are presented in Table 3.4. The percentage differences ranged from <1% (niacin) to 20.0% (thiamin). Most of the nutrients appeared to be higher in the CFFQ-2 however, only thiamin, riboflavin, vitamin B_{12} and iron were significantly higher (p<0.05). When milk intake was excluded from analysis the difference in vitamin B_{12} was no longer statistically significant (p>0.05). The CFFQ-2 was significantly higher for protein, folate, selenium, thiamin, riboflavin and iron (p<0.05; all medium effect size r=0.3). When the data was adjusted for energy intake, there were no longer any statistical differences between the nutrient intakes for the CFFQ-1 and the CFFQ-2 (p>0.05; Supplementary Table 5).

Pearson correlation coefficients between the CFFQ-1 and CFFQ-2 ranged from 0.40 (folate) to 0.82 (vitamin B_{12}) with an average correlation of 0.67 (all $p<0.01$). Folate and selenium had acceptable correlations (r=0.20-0.49), with the remainder of nutrients showing good correlations (r≥0.50). When milk intake was excluded from analysis correlations ranged from 0.41 (folate) to 0.73 (saturated fat and calcium) with an average correlation of 0.62 (all $p<0.01$). With milk excluded, selenium improved to have good correlation (r≥0.50) and vitamin C was reduced to an acceptable correlation (r=0.20-0.49). Folate had an acceptable correlation for both datasets. When adjusted for energy intake, correlations were similar to the unadjusted data (range 0.34 (folate) to 0.80 (zinc); average correlation of 0.63). Folate and selenium both still showed acceptable correlations (r=0.20-0.49), with the remainder of nutrients still showing good correlations (r≥0.50).

Table 3.4 Mean daily nutrient intake over four days and correlations between the CFFQ-1 and CFFQ-2 among infants aged 9-12 months (n=93).

Nutrients	*Milk included* [b]						*Milk not included* [c]					
	CFFQ-1 Daily intake[a]	*CFFQ-2 Daily intake*[a]	*Mean difference (%)*[d]	*Paired t-test (p-value)*	*Effect size*	*Correlation Coefficients* [e]	*CFFQ-1 Daily intake*[a]	*CFFQ-2 Daily intake*[a]	*Mean difference (%)*[d]	*Paired t-test (p-value)*	*Effect size*	*Correlation Coefficients* [e]
Energy (kJ)	3284 ± 1047	3239 ± 905	-1.4	0.61	_	0.62†	1638 ± 774	1765 ± 893	7.7	0.06	_	0.72†
Protein (g)	27.0 ± 10.5	28.7 ± 11.3	6.4	0.07	_	0.66†	18.2 ± 9.9	20.3 ± 11.3	11.9	0.01	0.3	0.71†
Fat (g)	36.9 ± 13.4	35.6 ± 9.9	-3.6	0.22	_	0.63†	15.0 ± 8.6	16.2 ± 9.8	7.5	0.18	_	0.63†
Saturated fat (g)	16.2 ± 6.1	15.7 ± 4.6	-2.8	0.36	_	0.64†	4.5 [3.6 - 5.5]	5.1 [4.3 - 6.1]	13.3	0.08	_	0.73†
Carbohydrate (g)	83.0 ± 29.8	81.3 ± 28.2	-2.1	0.51	_	0.63†	42.6 ± 24.0	45.2 ± 26.3	6.2	0.20	_	0.70†
Fibre (g)	6.8 ± 3.6	7.1 ± 4.0	4.5	0.37	_	0.63†	6.6 ± 3.6	7.0 ± 4.0	5.5	0.28	_	0.65†
Vitamin E (mg)	4.7 ± 2.4	4.5 ± 2.0	-4.2	0.24	_	0.73†	1.9 ± 1.2	2.0 ± 1.2	2.4	0.72	_	0.53†
Folate (µg)	114.9 ± 53.1	131.2 ± 90.8	14.2	0.07	_	0.40†	96.0 ± 51.9	114.4 ± 92.4	19.3	0.04	0.2	0.41†
Potassium (mg)	1066 ± 439	1087 ± 440	2.0	0.62	_	0.58†	674 ± 369	706 ± 443	4.9	0.39	_	0.61†
Calcium (mg)	491 ± 247	506 ± 251	3.0	0.40	_	0.76†	186 ± 119	206 ± 162	10.6	0.09	_	0.73†
Zinc (mg)	5.1 ± 2.3	5.1 ± 2.1	1.3	0.69	_	0.76†	2.4 ± 1.3	2.7 ± 1.5	10.0	0.05	_	0.66†
Selenium (µg)	22.8 ± 8.2	23.4 ± 10.5	2.9	0.53	_	0.45†	11.2 ± 7.2	13.3 ± 10.4	17.9	0.04	0.2	0.51†
Thiamin (mg)	0.5 [0.5 - 0.6]	0.6 [0.5 - 0.7]	20.0	0.01	0.3	0.67†	0.3 [0.2 - 0.3]	0.4 [0.3 - 0.4]	33.3	<0.01	0.3	0.62†
Riboflavin (mg)	0.7 [0.6 - 0.8]	0.8 [0.7 - 0.9]	14.3	<0.01	0.3	0.75†	0.3 [0.3 - 0.4]	0.4 [0.3 - 0.5]	33.3	0.04	0.2	0.59†
Niacin (mg)	4.7 [4.2 - 5.2]	4.7 [4.3 - 5.2]	<1	0.70	_	0.71†	2.6 [2.3 - 3.0]	2.9 [2.5 - 3.3]	11.5	0.13	_	0.61†
Vitamin C (mg)	49.0 [44.2 - 54.3]	47.3 [42.5 - 52.7]	-3.5	0.43	_	0.65†	18.4 [16.1 - 21.2]	18.4 [15.9 - 21.4]	<1	0.99	_	0.44†
Vitamin B_{12} (µg)	0.9 [0.8 - 1.1]	1.1 [0.9 - 1.2]	22.2	0.02	0.2	0.82†	0.6 [0.5 - 0.7]	0.7 [0.6 - 0.8]	16.7	0.07	_	0.69†
Iodine (µg)	39.4 [34.3 - 45.1]	41.0 [35.9 - 46.7]	4.1	0.41	_	0.75†	8.7 [7.2 - 10.6]	9.5 [7.6 - 11.8]	9.2	0.31	_	0.67†
Iron (mg)	4.3 [3.7 - 4.9]	4.8 [4.2 - 5.5]	11.6	0.01	0.3	0.80†	2.5 [2.2 - 2.8]	2.8 [2.5 - 3.2]	12.0	<0.01	0.3	0.66†

CFFQ-1, First complementary food frequency questionnaire; CFFQ-2, Second complementary food frequency questionnaire. [a] mean ± SD or geometric mean [95% CI]; [b] Unadjusted raw dietary data with milk (breast milk and formula) intake included; [c] Excludes milk (breast milk and formula) from analysis; [d] Mean difference calculated as CFFQ2-CFFQ1/CFFQ1, [e]Pearson's Correlation Coefficients; † *p*=<0.01, significant difference (2-tailed). Effect size: ≥0.5, large; 0.3, medium; 0.1 small effect (Field, 2013).

Cross-classification and weighted kappa

On average, 59.6% (mean) of participants were correctly classified into the correct tertile for both the CFFQ-1 and CFFQ-2 (range 40.9% (fat) to 72.0% (vitamin B_{12}); Table 3.5). All nutrients and energy showed good cross-classification (>50% correctly classified) apart from fat and saturated fat (40.9% and 47.3%, respectively). The average of participants grossly misclassified was 6.1% (mean) ranging from 2.2% (vitamin B_{12} and iodine) to 9.7% (energy). All nutrients showed acceptable agreement between the CFFQ-1 and CFFQ-2 (κ=0.20-0.60) apart from zinc, vitamin B_{12} and iron, which showed good agreement (κ>0.60).

When milk intake was excluded, the mean number of participants correctly classified was 58.2% (range 48.4% (niacin) to 65.6% (energy)). Fat and saturated fat now showed good cross-classification (>50% in same tertiles), but niacin showed poor cross-classification (48.4%). Similarly, all nutrients showed low levels of misclassification (<10% grossly misclassified) except niacin (10.8%). All nutrients showed acceptable agreement between the CFFQ-1 and CFFQ-2 (κ=0.20-0.60).

When adjusted for energy intake, the average number of participants correctly classified was 59.8% (mean), ranging from 47.3% (selenium) to 71.0% (saturated fat) (Supplementary Table 6). Fat and saturated fat again showed good cross-classification (>50% participants correctly classified), however folate and selenium showed lower levels of participants classified correctly (poor classification; 48.4% and 47.3%, respectively). All nutrients continued to have low levels of participants grossly misclassified (all <10% in opposite tertiles). All nutrients showed acceptable agreement between the CFFQ-1 and CFFQ-2 (κ=0.20-0.60) apart from saturated fat, which showed good agreement (κ>0.60).

Table 3.5 Cross-classification by tertiles of nutrient intakes and weighted kappa based on the CFFQ-1 and CFFQ-2 among infants aged 9-12 months (n=93).

	Milk included [b]			*Milk not included* [c]		
Nutrients	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*
Energy (kJ)	55.9	9.7	0.40	65.6	5.4	0.55
Protein (g)	59.1	8.6	0.44	62.4	4.3	0.52
Fat (g)	40.9	6.5	0.25	58.1	9.7	0.41
Saturated fat (g)	47.3	8.6	0.30	52.7	5.4	0.40
Carbohydrate (g)	60.2	7.5	0.46	61.3	8.6	0.46
Fibre (g)	52.7	8.6	0.37	52.7	8.6	0.37
Vitamin E (mg)	59.1	4.3	0.49	60.2	5.4	0.49
Folate (µg)	57.0	7.5	0.43	60.2	7.5	0.46
Potassium (mg)	58.1	8.6	0.43	64.5	3.2	0.56
Calcium (mg)	66.7	4.3	0.57	60.2	1.1	0.54
Zinc (mg)	71.0	4.3	0.62	62.4	4.3	0.53
Selenium (µg)	54.8	6.5	0.42	63.4	4.3	0.54
Thiamin (mg)	55.9	5.4	0.44	62.4	6.5	0.50
Riboflavin (mg)	63.4	4.3	0.54	58.1	6.5	0.45
Niacin (mg)	63.4	8.6	0.49	48.4	10.8	0.30
Vitamin C (mg)	64.5	5.4	0.54	50.5	8.6	0.34
Vitamin B_{12} (µg)	72.0	2.2	0.66	55.9	6.5	0.41
Iodine (µg)	59.1	2.2	0.51	57.0	3.2	0.48
Iron (mg)	71.0	3.2	0.63	50.5	7.5	0.36

CFFQ-1, First complementary food frequency questionnaire; CFFQ-2, Second complementary food frequency questionnaire.
[b] Unadjusted raw dietary data with milk (breast milk and formula) intake included; [c] Excludes milk (breast milk and formula) from analysis

NOTE: Participants were in tertiles, 3 groups of 31 participants

3.5 Discussion

The relative validity and reproducibility of the CFFQ to assess nutrient intakes of NZ infants aged 9 to 12 months were examined. The CFFQ was compared to a 4dWFR as a reference standard to assess validity and then the CFFQ was repeated a second time to assess reproducibility. The CFFQ showed adequate performance with acceptable to good validity for most nutrient intakes (although minimum agreement criteria were not met for fat, saturated fat, fibre and selenium; $r \leq 0.50$ and <50% correctly classified and/or >10% grossly misclassified and $\kappa < 0.40$). The relative validity of the CFFQ was consistent if not improved following adjustment for energy whereas removing breast milk and infant formula intake from the data reduced the agreement between methods. The CFFQ showed good reproducibility when administered four weeks apart. Given the challenges of employing weighed food records in large studies, the CFFQ appears to provide a practical alternative for semi-quantitative assessment of nutrient intake in infants during the period of complementary feeding and may be useful in cohort studies to compare groups and assess the effect of interventions on early nutrition.

3.5.1 Validity

Energy intake was similar between the CFFQ and 4dWFR. Although the CFFQ overestimated intake of fat, overall there was a tendency to underestimate nutrient intake, including for carbohydrate, fibre, folate, potassium, thiamin, riboflavin, niacin, and vitamin C. In contrast, other studies in preschool children have generally shown that FFQs overestimate energy and nutrient intake (Andersen et al., 2003; Bell et al., 2013; Gondolf et al., 2012; Marriott et al., 2009; Marriott et al., 2008; Palacios et al., 2017; Watson et al., 2015). These studies varied in methodology, nutrients assessed, reference methods and timeframes. They also included children outside of the narrow age-range in our study, and so may not be directly comparable.

A likely contributor to the under- and overestimation of nutrients in FFQs is the difficulty in adequately estimating portion size, particularly in infants, as they typically taste food without eating the whole portion, making actual intake hard to quantify. Furthermore, the 4dWFR in this study would have collected more detailed information on daily intake,

including food and drinks not necessarily part of a planned meal, which could be more easily forgotten and omitted from the CFFQ due to its retrospective nature. Adjusting for energy intake may be useful in mitigating the effects of measurement error (Andersen et al., 2003) and improve the level of agreement for individual nutrients. When assessing groups such as in clinical studies, energy-adjustment helps to highlight the quality of dietary intake. Energy adjustment for this reason can be advantageous in analyses of diet-disease associations however interpretation of energy-adjusted data is not straightforward and should be justified in clinical studies (Willett, Howe & Kushi, 1997). More consistent results for all nutrients was found with energy adjustment. For the energy-adjusted data, the CFFQ is able to adequately rank infants for most nutrients except fibre ($\kappa<0.20$).

Despite the CFFQ underestimating some nutrient levels compared to the 4dWFR, the clinical significance of these differences may be small. Using the Nutrient Reference Values (NRV) for infants (aged 7 to 12 months), the interpretations of nutrient intakes were the same for both methods. For example, folate levels (µg) from both the 4dWFR and CFFQ-1 were well within the NRV of 80 µg per day (137.8 ± 74.7 vs. 115.1 ± 54.2 (mean ± SD), respectively) (National Health and Medical Research Council, 2006). Therefore, the CFFQ could be more useful for assessing dietary adequacy rather than absolute nutrient intake, as the interpretation is likely to be similar to a 4dWFR.

Another likely reason for the small discrepancies between methods may be the difficulty in accurately obtaining the detail on the types, amounts and frequency of foods consumed from the CFFQ. The CFFQ did not specify that more than one type and brand of food could be described for each option. For each food item participants were asked to specify the brand and type in the corresponding textbox (e.g. bread they could put 'multigrain' or 'Molenberg' bread). Most participants just put one option in each textbox, which might not have been representative of total intake where there is a combination of foods included (e.g. both brown and white bread) and hence the CFFQ not capturing as detailed nutrient intake as the reference method (4dWFR). Portion size may also have been under- or overestimated due to the limited detail obtained as the 'frequency' and

'amount' options were set. Participants could choose between a frequency of 0 to 10+ times a day and portions from 0 to 6 Tbsp and up to ½ cup when fed.

Including milk intake in our analysis did not change the overall interpretations of the CFFQ; in fact, we found less agreement and weaker associations between methods when milk intake was excluded. As milk intake is a major contributor to an infant's energy and nutrient intake, it is important to be able to quantify total nutrient intake with this included. Milk intake (particularly breast milk intake) has been handled differently in validation studies in young children (0-24 months). Watson et al. (2015) excluded milk from their validation study which despite being a limitation of their findings, they investigated nutrient intake in toddlers not infants, so breast milk was likely to only contribute a small amount to total nutrient intake. However, in infants less than 12 months of age, milk typically contributes a third or more to nutrient intake. In infants, information on the frequency and duration of breastfeeds was collected to calculate the volume of milk consumed (Andersen et al., 2003; Marriott et al., 2009; Marriott et al., 2008; Palacios et al., 2017). It has been suggested that breast milk quantification is a contributor to the overestimation of nutrient intakes (and lower correlations) in infants (Marriott et al., 2008). Most studies however, did not assess the impact excluding milk had on their results. The more recent validation study by Palacios et al. (2017) is the only study to our knowledge that analysed data with both milk intake included and excluded and found similar results to our study, despite including infants and toddlers.

Most studies involving nutrient assessment tools rely on correlations to assess validity, despite correlations not measuring agreement between methods (Bland & Altman, 1986). A systematic review of validation studies in infants and preschool children (0-5 years) by Ortiz-Andrellucchi et al. (2009) found good correlations for niacin, thiamin, vitamins C and E, riboflavin, calcium, potassium, iron and zinc (r=0·55-0·69) when using a reference method that reflected short-term intake. A more recent review of validation studies in toddlers (12-24 months) also found acceptable correlations (r=0.30-0.50) for vitamin C and iron and good correlations for calcium (r>0.51) (Lovell et al., 2017). Despite different methodologies and age ranges these results compare favourably with

the nutrient correlations in our study (r=0.50-0.81) except for vitamin E, which showed a lower (but still acceptable) correlation (r=0.47). Our correlations were however, generally higher than that found in another review of FFQs in children (0-24 months) by Bell et al. (2013) which found poor to acceptable correlations for energy and nutrients.

Correlation coefficients are affected by the agreement of the reference data, mode of administration, age, sex and ethnicity of the study population (Preston et al., 2011). Despite only using 4 days of records in the current study, there were comparable Pearson correlation coefficients (mean r=0.52, range 0.18-0.81) to those found by Andersen et al. (2003) using a 7dWFR in 12-month infants (n=64; r=0.50, range 0.18-0.72) and Marriott et al. (2008) using a 4dWFR in 6-month infants (n= 50; r=0.63, range 0.39-0.86). This was likely due to our larger sample size and narrow age-range (infants 9-12 months) compared to younger infants (with less varied diets, and improved associations) and older infants (with more varied diets and likely reduced associations). The slightly higher correlation coefficients by Marriott et al. (2008) are likely due to this study using an interviewer-led questionnaire, which tends to improve the correlations found (Cade et al., 2002).

Despite the interpretations remaining similar, adjusting for energy intake improved the range in correlations between dietary assessment methods (range r=0.24-0.78). This was similar to the observations of Marriott et al. (2008) (r=0.55-0.89) and Andersen et al. (2003) (range 0.16-0.79). Marriott et al. (2008) generally found slightly higher correlations for the same nutrients, possibly because the infants were younger (6 months) with less dietary variation than the infants in our study who were transitioning to family foods. In their other study in older infants (12 months), slightly lower correlations were found (r=0·24-0·75) (Marriott et al., 2009). These findings suggest that higher correlations are likely attributable to the younger age-range, and hence the differences with other studies that include infants older than 12 months.

Most validation studies rely on correlation coefficients but as they only measure the degree to which dietary assessment measures are associated, they do not show absolute agreement. Comparatively, cross-classification gives a much clearer and undistorted picture of how well a FFQ performs (Cade et al., 2002). Nelson et al. (1989)

found a 7dWFR would correctly classify 80% of toddlers into the extreme thirds of the distribution according to intakes of macronutrients, thiamin, riboflavin, calcium, iron and vitamin C. The agreement across tertiles between the two methods obtained in our study was lower than this, (mean 53.9% (range 39%-67%) for correct classification) likely related to the greater variability in food intake found in infants as they transition to family foods and the fewer number of recording days (4dWFR vs. 7dWFR). Our results were higher than that of the studies in infants and toddlers found in the systematic review by Bell et al. (2013) (average 36-38% correctly classified). The level of misclassification into opposite tertiles of 7.1% (range 2%-14.7%) however, was slightly higher than the review (3-5% classified into opposite tertiles or quartiles). Many of the validation studies available have ranked participants into quartiles, not tertiles so the ability to compare results is limited. Validation studies in older children (10-16 years) found lower levels of correctly classified participants into quartiles for macronutrients, calcium, iron, magnesium, vitamin C, folate, vitamin B_6 and vitamin B_{12} (range 21.9-33.3%) (Preston et al., 2011). Using quartiles decreases the proportion of participants correctly classified and misclassified compared to tertiles and hence could explain some of the differences present.

A recent validation study including infants and children aged 0 to 24 months found most children were correctly classified into the same or adjacent quartile (mean of 83%) by both assessment methods, with the highest for zinc (93%) and the lowest for copper (70%) (Palacios et al., 2017). This study had higher levels of misclassification (average 17%, range 7%-30%) than our tool, likely as they included some nutrients we did not (e.g. copper) that may have been harder to classify, and they used a weaker reference method (multiple 24HR) that can have more correlated errors to the FFQ (including reliance on memory and conceptualisation of portions sizes (Cade et al., 2002)). Multiple 24HR have been found to accurately reflect energy intake depending on the number of days assessed, although they are not precise at the individual level (Livingstone & Robson, 2007). The low rates of misclassification in our study were also reflected by Watson et al. (2015) and likely enhanced in the current study by the level of detail of information collected, including brands and types of baby foods and formulas used (Ortiz-Andrellucchi et al., 2009). The CFFQ could be a useful tool for identifying infants

with extremes of dietary intake and an appropriate method for ranking infants according to nutrient intakes. The lower level of agreement (κ<0.20) and higher rates of misclassification for saturated fat and selenium intake were consistent (as seen when comparing misclassification between reproducibility and validity studies) meaning the CFFQ may still be useful for comparing population groups for these nutrients. When assessing nutrient density (i.e. adjusted for energy intake), the CFFQ has acceptable ability to rank infants for nutrient intake but poor ability to rank infants for intakes of fibre (κ<0.20). It is possible that longer periods of recording may improve the agreement of these methods for these nutrients, but the increased risk of participant burden needs to be considered.

Bland-Altman analysis in validation studies in young children have shown large limits of agreement (Andersen et al., 2003; Bell et al., 2013) with a mostly positive mean bias (Bell et al., 2013; Marriott et al., 2008) or a systematic increase in differences with increasing intakes for most nutrients (Andersen et al., 2003). Bland-Altman analysis and linear regression analysis in this study indicated good agreement between the CFFQ and 4dWFR. The plots show some outliers attributed to a small number of participants where differences between the CFFQ-1 and 4dWFR were large. When adjusted for energy intake, no proportional bias was seen for any of the nutrients indicating agreement between methods across the mean intake of these nutrients.

3.5.2 Reproducibility

The CFFQ showed good reproducibility, with all nutrients comparable between administrations (p>0.05) apart from thiamin, riboflavin, vitamin B_{12} and iron, which were higher in the CFFQ-2. Similar trends were seen when milk data was eliminated but no longer seen when looking at nutrient density. This differed from the findings of Metcalf et al. (2003) in NZ children 1 to 14 years who despite looking at food groups not nutrients, found higher levels in the first FFQ not the second FFQ. In a more recent validation study in infants, no difference in the interpretation of results was observed when using the first or second FFQ (Palacios et al., 2017). Reproducibility of a FFQ has been shown to be affected by several factors including ethnicity, sex, age and education (Preston et al., 2011).

Correlation coefficients for repeatability between CFFQ administrations showed good associations (r≥0.50) except for folate and selenium, which showed acceptable associations (r=0.20-0.49). All nutrients showed good cross-classification (>50% correctly classified and <10% grossly misclassified) apart from fat and saturated fat. However, overall the CFFQ showed acceptable to good agreement for all nutrients (κ>0.20). The CFFQ preformed best with milk included, but similar results were seen across all data adjustments. A review of 227 validated FFQs by Cade et al. (2002) found only 47% of FFQs were tested for reproducibility, and these FFQs generally had good correlations between administrations (r=0.5-0.7), with higher correlations found for data collected for one month or less. Despite none of these studies assessing infant diets, our findings were very comparable, particularly for the associations for fat (r=0.63 vs. 0.60), energy (r=0.62 vs. 0.63) and vitamin C (r=0.65 vs. 0.66; respectively), likely due to the short timeframe between administrations, and therefore more stable dietary patterns captured in infants of this age. Our unadjusted results were very similar to the findings of Watson et al. (2015) in NZ toddlers who adjusted nutrient data for fruit and vegetable intake. Their results ranged from 0.65 for vitamin C to 0.75 for calcium (similar to 0.65 (vitamin C) and 0.76 (calcium) in our study), however our study had a larger range (r=0.40 (folate) to 0.82 (vitamin B_{12})), as we included different micronutrients. Therefore, this CFFQ showed good reproducibility in infants of 9 to 12 months of age.

3.5.3 Strengths and limitations

There are many aspects of FFQ design that increase validity in toddlers, including administration method, validation and reproducibility methods, and statistical analyses (Lovell et al., 2017). One of the strengths of the current research is the study design, which assessed both validity and reproducibility for the CFFQ. This is important given that high validity does not necessarily result in good reproducibility. Using the WFR as a reference method is the preferred method for assessing dietary intake in infants (Luque et al., 2013) and has shown acceptable validity in this study. We used four days of recall for both the CFFQ and WFR so we could effectively measure the same foods and nutrients and capture a similar number of days to assess nutrient intake as determined by other studies in infants (Lanigan et al., 2001; Marriott et al., 2009; Marriott et al.,

2008). Shorter versions of FFQs may improve the validity and reproducibility (Cade et al., 2002) but some nutrients require more than four days to accurately assess intake in children 6 to 24 months of age (Lanigan et al., 2004). It is likely that some of the nutrients with poorer agreement such as selenium and saturated fat, may have needed longer periods of recall to assess these adequately.

We also gathered enough detail from the CFFQ to give adequate agreement between methods for this short time of recall. This included the amount and frequency of consumption of all foods and drinks, information on brands and types of baby foods and milks and formulas. We did ask for supplementation information when gathering data but did not include this in our analyses as only three participants were using supplements (generally a probiotic so unlikely to impact on nutrient intake). Portion size estimation can be a big contributor to errors in reporting dietary intake, which could be amplified in the infant population considering they eat small amounts and food is spilled and wasted. This was addressed in the present study with gathering information on food eaten and left over (including spilled or wasted), adapting the CFFQ to include teaspoon and tablespoon measurements (more closely related to the small intake in infants compared to cups) and providing instructions on how to best estimate if weighing was unavailable (e.g. using the child's palm).

A potential limitation is that only 51% of those that registered interest in the study, were able to complete it. Both the population group (infants) and the reference method (WFR) used in this study made it difficult for many parents to commit. However, considering the many challenges of assessing dietary intake in infants and the lack of tools already available, there were still a good number of participants (n=95) able to complete the study. Previous studies in infants (<12 months) have only included 50 to 65 participants (Andersen et al., 2003; Marriott et al., 2008). For validity statistics a minimum of 50 participants is needed, which might explain some of the differences in statistical results discussed above (Cade et al., 2002). Another limitation of this however, was the self-selected population, but in order to validate the CFFQ, motivated individuals are needed to complete it, so this does not necessarily make our results less valid.

Another limitation of our study is that few ethnic minorities were included, and it is possible that the diets of these infants are slightly different to that of European infants. For example, lower correlation between FFQs and reference methods have been observed in Pacific children (Metcalf et al., 2003). However, the study sample included participants from both urban and regional areas around New Zealand and thus is likely to be representative of the wider population. Demographic data was unavailable for 79% (73 participants) of those that dropped out prior to completing the CFFQ-1, so it is difficult to assess if any differences might have been present compared to those who completed the study. It is possible that Māori and Pacific participants may have needed alternative approaches to get them to engage.

As discussed, correlations alone are not appropriate to assess agreement, only associations, so the use of a variety of statistical methods (including cross-classification and Bland-Altman analysis) further strengthens our findings regarding the reproducibility and validity of the CFFQ. We also explored adjusting the data to assess the impact of milk intake and energy intake on the results. As intake of several nutrients is associated with energy intake (Willett & Lenart, 2013) adjusting for energy intake is likely to improve the relative validity.

One limitation of our methods is the use of different methodology to *estimate* dietary intake (one is retrospective, the other is prospective) and the timing between commencing methods varied. Any discrepancies between dietary assessment tools cannot be quantified due to these differences. Infants may have had different intakes at the time of completing the CFFQ compared to when the 4dWFR was completed if left for too long, as they are introduced to a bigger variety and quantity of food within a short time at this age. However, participants could remember the answers from one method if administered too close together also increasing the bias between methods. Alternative methods (collecting plasma or urine to test for dietary biomarkers or doubly labelled water technique) are expensive, invasive and inefficient when looking at multiple nutrients, so the WFR was deemed the best reference method to use. Estimating potion size can be one of the biggest sources of error, so including books with portions size and example measures to aid food estimation may help with this in further

research (Andersen et al., 2003; Conn et al., 2009; Lioret et al., 2013; Preston et al., 2011).

Not all participants started the 4dWFR immediately after completing the CFFQ-1 due to the infant being unwell or teething, or the parent became too busy to complete it. If data was to be collected during this time, the diet may not have been a good representation of 'usual' intake, due to changes in appetite as a result of the infant's health and/or underreporting or changes to food intake behaviour (such as selecting foods that are less difficult to weigh) due to the burden of the 4dWFR.

3.6 Conclusions

In conclusion, the CFFQ was able to capture relatively valid estimates of 14 out of 19 nutrients in a group of NZ infants (9-12 months) compared to a 4dWFR and demonstrated good reproducibility for assessing energy and 18 nutrients. Although some of the CFFQ estimates were systematically lower when compared to the reference method, the CFFQ is an acceptable method for ranking individuals. Adjusting nutrient intake for energy improved the validity between methods and may be preferred for future research that focuses on diet quality. Therefore, this CFFQ could be used to monitor and compare intake of nutrients in groups of infants who are progressing with complementary foods where a simple tool is needed with little participant burden. The CFFQ could help assess dietary adequacy from early on in life and investigate the impact of interventions aimed at improving early growth and nutrition.

3.7 Acknowledgements

We acknowledge the 186 parents who volunteered to participate in this study and are thankful for the final 95 infants and their families who put the time in and were able to complete the study.

3.8 Author contributions

Amy Judd was the primary researcher responsible for recruitment and data collection, statistical analysis, formulation of results and the manuscript. Ashleigh Jackson also contributed to recruitment and data collection. Dr Cath Conlon assisted with gaining ethical approval and supervised the progression of the research process through to the final manuscript. Dr Kathryn Beck assisted with statistical analysis, formulation of results and revision of the manuscript and Dr Christopher McKinlay provided feedback on the final manuscript. All authors have reviewed the final manuscript.

3.9 Conflicts of interest

The authors declare no conflicts of interest.

Chapter 4. Conclusions and recommendations

Dietary assessment in infants is important not only because of concerning rates of inadequate intake of some nutrients (Conn et al., 2009; Soh et al., 2002) but also because eating habits as early as nine months of age can influence dietary patterns throughout childhood (Lioret et al., 2013) impacting on health in later life (Watson et al., 2015). There are few instruments available to capture nutrient intake in infants, and to our knowledge there are no validated tools available for use in NZ infants in the first year of life.

The performance of the CFFQ in this study was considered adequate when a correlation coefficient was above 0.50, and 50% of subjects were classified correctly into the same tertile and less than 10% grossly misclassified into opposite tertiles, or weighted kappa values of at least 0.4 were found (Masson et al., 2003). The CFFQ showed adequate performance with acceptable to good validity for assessing nutrient intake (aside from fat, saturated fat, selenium, and fibre) in NZ infants aged 9 to 12 months, when compared to a reference method of a 4dWFR. It is likely that some of these nutrients with poorer agreement, such as selenium, which are found in fewer foods may have needed longer periods of recall to assess these adequately. Although the CFFQ overestimated intake of fat, overall there was a tendency to underestimate nutrient intake, including for carbohydrate, fibre, folate, potassium, thiamin, riboflavin, niacin, and vitamin C. When administered four weeks apart, the CFFQ showed good reproducibility for assessing energy and nutrient intake. Adjusting the CFFQ data for energy intake improved the agreement between methods. Removing breast milk and formula intake from the data reduced the agreement between methods.

4.1 Strengths and limitations

This work had a number of strengths and limitations, this included our sample size, our reference method, the perceived burden of taking part, as well as the difficulties in estimating breast milk consumption.

4.1.1 Sample size and population

For validity statistics in adults, a minimum of 50 participants is needed, which was well exceeded in our study of infants (n=95) (Cade et al., 2002). Infants are a difficult group to assess dietary intake in which resulted in only 51% of those that registered being able to complete the study. Several participants dropped out of the study due to changes in an infant's appetite (teething changing the foods accepted or illness impacting appetite). It is also possible that some of the infants included in the study had these same issues, and hence the diet was not a true reflection of their usual intake. A limitation of the current study is information on carer education was not collected. As this was a convenient sample of participants, it is likely that parents in this group may be more health conscious or motivated than the general population, impacting the manner and interest they put into the WFR and CFFQ. Participants also required a degree of literacy and access to a computer or smartphone in order to complete the study.

4.1.2 Reference method - weighed food records

Weighed food records impose a high participant burden, especially in infants as they do not always consume everything offered, and they rely on a co-reporter to complete everything for them. However, WFRs are the preferred reference method when assessing FFQs (Cade et al., 2002). Our methodology tried to reduce this burden as much as possible (by using fewer recording days), however it is likely that some misreporting and changes to the selection of foods (particularly if they were difficult to quantify and weigh) would have occurred. Many infants have multiple carers and may have required more than one parent to complete the record for them (e.g. day care staff) likely to further increase the errors in methods. As mentioned, quantifying infant dietary intake is difficult as they tend to have small tastes of different foods without necessarily swallowing it all. They also have new foods introduced with incremental quantities as they develop from 6 to 12 months. Despite biomarkers being advantageous in this regard, as they estimate intake independent of participant reported intake (Cade et al., 2002), they were not appropriate for this study, but this could be a future avenue for research.

4.1.3 Quantifying breast milk intake

Another challenge was quantifying breast milk intake, as unlike formula, breast milk could not be weighed so was not measured in either method. Instead we relied on estimates based on the duration and frequency of feeding as used in other studies that included breast milk consumption (Andersen et al., 2003; Marriott et al., 2009; Marriott et al., 2008; Palacios et al., 2017). This creates a barrier for validating nutrient intake, as we were unable to validate breast milk consumption. Stable isotopes methodology is one way of assessing breast milk intake but is expensive and relies on specialised techniques. Conn et al. (2009) found Australian breastfed infants had more diverse diets (when assessing food groups) than non-breastfed infants. Breast milk quantification is a potential contributor to the overestimation of nutrient intakes (and lower correlations) in infants (Marriott et al., 2008). Including milk intake in our results appeared less problematic, as it did not change the overall interpretations of our tool. We found less agreement and associations between methods when milk intake was excluded, but this included both breast milk estimation and weighed formula. Milk intake is a major contributor to an infant's energy and nutrient intake, so a tool needs to be able to quantify total nutrient intake with this included. We found most infants were offered solids before milk at the time of the study (70.5%), which is in line with the Ministry of Health recommendations from 8 months of age. As nearly a third of infants in this study were still consuming milk first, milk estimation could still be a contributor to discrepancies in our results. We did find inconsistencies in the breast milk intake recorded in some of the food diaries compared to that estimated on the CFFQ, which suggested not all milk intake had been recorded on the food diary. This could also impact the validity of the CFFQ and hence, further research could explore this.

4.1.4 Statistical strengths

A variety of statistical methods is recommended to assess both validity and reproducibility of a dietary assessment tool. The use of cross-classification and Bland-Altman analysis in addition to the correlations usually reported, further strengthened the conclusions regarding validity and reproducibility of the CFFQ. We also explored adjusting the data to assess the impact of milk intake and energy intake on the results. This confirmed including breast milk intake (despite being an estimate), was not an issue

with this tool when assessing validity and adjusting nutrient intake for energy improved the agreement of this tool with a 4dWFR.

4.2 Impact of research and recommendations

As the CFFQ has been validated for the assessment of nutrient intake in infants 9 to 12 months, it could be used in larger research studies to assess nutrient intake in this age group. It could then be used to assess adherence to nutrition guidelines in both the clinical and research setting and could be incorporated into a screening tool to identify those that would benefit from further nutritional support.

There are several recommendations for future research which include:

- Assessing the validity and reproducibility of the CFFQ within specific ethnic groups such as Māori, Asian and Pacific population groups
- Assessing the ability of the CFFQ to assess nutrient intake in groups of infants at high risk of nutrient deficiency (e.g. iron deficiency)
- Further assessing the impact of breast milk, infant formula and other fluids on the validity and reproducibility of the CFFQ
- Assessing the ability of the CFFQ to assess selenium, fibre and energy intake in a larger population group
- Enhancing the CFFQ to gain more detailed information on components such as:
    - including columns so more than one type of cracker, cereal, rice, yoghurt or bread can be recorded if needed (frequency, amount and type)
    - creating questions to capture cow's milk intake as currently participants were unable to record milk they had with food (e.g. on cereal or Weet-Bix)
    - create more space for participants to add 'other' foods consumed but ensure these are linked with columns collecting information on frequency and amount.

4.3 Conclusion

A comprehensive literature review was conducted on dietary assessment tools in infants and found few valid dietary assessment tools exist for use in infants aged less than 12 months. Dietary assessment tools need to be used specifically in the population they have been designed for. To our knowledge this is the first dietary assessment tool in New Zealand that has been tested for relative validity and reproducibility to assess nutrient intake in infants aged 9 to 12 months.

The objective of the present study was to investigate the relative validity and reproducibility of a CFFQ to assess nutrient intake in infants aged 9 to 12 months. Validity was assessed by comparing the energy and nutrient intakes from the CFFQ to that obtained from a four-day weighed food record. The CFFQ provided valid estimates of intake for 14 out of 19 nutrients in infants (9-12 months) compared to a 4dWFR. Adjusting nutrient intake for energy resulted in a modest improvement in validity and may be preferred for assessments focusing on diet quality. The CFFQ demonstrated good reproducibility for all nutrients. The CFFQ is a valid tool for semi-quantitative assessment of nutrient intake and diet quality, and can be used for monitoring intake over time. The CFFQ may be particularly useful where a simple tool is needed with little participant burden to compare groups of infants who are progressing with complementary foods, including identification of unhealthy early dietary practices and to investigate the impact of interventions aimed at improving early growth and nutrition.

Chapter 5. Appendices

Appendix A: Complementary Food Frequency Questionnaire (CFFQ)

Feeding Assessment Tool (Section 4 includes the CFFQ)

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Feeding Babies Study 2017-18

1. Section 1. Growth

We are recruiting ALL parents and caregivers of babies (healthy term) aged 9+ months who are currently living in New Zealand.

This questionnaire asks about how your baby has been fed over the last 4 days. There are no "right" or "wrong" answers.

All of the data collected is anonymous and your answers will be held in strict confidence.

* 1. Please enter your six digit study ID number. You can find this number on your food diary provided in your information pack

2. What is your child's date of birth?

Date / Time

DD/MM/YYYY

* 3. Do you consent to taking part in this study?

- Yes
- No

* 4. Please record the most recent growth measurements from the**Well Child Book**

Weight

(_ _ . _kg)
(DD/MM/YYYY)

Head
circumference

(_ _ . _cm)
(DD/MM/YYYY)

Height

(_ _ . _cm)
(DD/MM/YYYY)

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2. Section 2. Feeding history - Milk & fluids

* 1. Was your baby ever breastfed?

- Yes
- No

* 2. Are you still breastfeeding

- Yes
- No

* 3. If no longer breastfeeding, how old was your baby when you stopped?

- Still breastfeeding
- 1-2 weeks
- 3-4 weeks
- 1-2 months
- 3 months
- 4 months
- 5 months
- 6 months
- 7 months
- 8 months
- 9 months
- 10 months
- 11 months

* 4. What were the main reasons for stopping breast feeding (tick all that apply)?

- [ ] Personal choice
- [ ] Going back to work
- [ ] Unable to express at work
- [ ] Breastfeeding was difficult
- [ ] I didn't have enough milk
- [ ] Baby seemed hungry
- [ ] Other (please describe)
- [ ] Concerned about baby's growth
- [ ] Recommended by family / friend
- [ ] Recommended by a health professional
- [ ] Found out I was pregnant
- [ ] Prefer not to answer

* 5. Has your baby had infant formula at any stage?

- ◯ Yes
- ◯ No

* 6. If yes, how old was your baby when formula was first introduced?

- ◯ No formula introduced
- ◯ 1-2 weeks
- ◯ 3-4 weeks
- ◯ 1-2 months
- ◯ 3 months
- ◯ 4 months
- ◯ 5 months
- ◯ 6 months
- ◯ 7 months
- ◯ 8 months
- ◯ 9 months
- ◯ 10 months
- ◯ 11 months

* 7. Has baby ever had standard milk?

- ◯ Yes
- ◯ No

* 8. If yes, how old was your baby when standard milk was first introduced?

- ◯ Never
- ◯ 1-2 weeks
- ◯ 3-4 weeks
- ◯ 1-2 months
- ◯ 3 months
- ◯ 4 months
- ◯ 5 months
- ◯ 6 months
- ◯ 7 months
- ◯ 8 months
- ◯ 9 months
- ◯ 10 months
- ◯ 11 months

* 9. Aside from breastmilk, formula or standard milk, has your baby had water on it's own?

- ◯ Yes
- ◯ No

* 10. What other fluids has baby had and when were they first introduced

	Not introduced	Yes at 1-2 weeks old	Yes at 3-4 weeks old	Yes at 1-2 months old	Yes at 3 months old	Yes at 4 months old	Yes at 5 months old	Yes at 6 months old	Yes at 7 months old	Yes 8 months old	Yes 9 months old	Yes 10 months old	Yes 11 months old
Cordial (raro)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Fizzy drinks	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Juice	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Milo	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tea	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

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3. Section 3. Feeding history - solids

* 1. How many months old was baby when he/she started eating solid food*?(appeared to swallow at least some of the food)*

- 4 or less
- 5
- 5 and a half
- 6
- 6 and a half
- 7
- 7 and a half
- 8
- 8 and a half
- 9
- 9 and a half
- 10
- 10 and a half
- 11 or more

* 2. Which foods did you introduce to your baby in the first 2 weeks after starting solids? (tick all that apply)

- [ ] Rusk
- [ ] Baby cereal or baby rice
- [ ] Breakfast cereal
- [ ] Yoghurt
- [ ] Red Meat
- [ ] Chicken
- [ ] Fish
- [ ] Ready-made baby food
- [ ] Taro
- [ ] Cassava
- [ ] Bok Choy
- [ ] Noodles
- [ ] Puha
- [ ] Fruit (please specify e.g. banana, apple etc)
- [ ] Vegetables (please specify e.g. kumara carrot etc)

Fruit or Vegetables (please specify)

3. If you used baby rice, which type did you give baby

- ○ Homemade
- ○ Commercial, please specify brand (eg Watties)
- ○ Not applicable

If commercial, please specify brand here

4. When baby first started eating solid foods, how were they fed?

- ○ Fed by adult
- ○ Mostly fed by adult, some self-feeding
- ○ About half fed by adult and half self-feeding
- ○ Baby mostly fed themselves, some feeding by adult
- ○ Baby fed themselves

5. How is baby fed now?

- ◯ Fed by adult
- ◯ Mostly fed by adult, some self-feeding
- ◯ About half fed by adult and half self-feeding
- ◯ Baby mostly fed themselves, some feeding by adult
- ◯ Baby fed themselves

6. When feeding baby, which do you give first?

- ◯ Milk before solids
- ◯ Solids before milk

7. Currently, how many solid meals does your baby usually have per day?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7 or more

8. Currently, how many solid snacks does your baby usually have per day?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7 or more

9. What type of foods do you use for baby most often?

- ◯ Homemade foods
- ◯ Commercially prepared foods (e.g. Watties)
- ◯ Combination

If using all or combination of commercial, please specify brand here

10. Has baby started eating red meat?

- ◯ Yes
- ◯ No
- ◯ Other (please specify)

11. If yes, how many months old was baby when red meat was first introduced?

- ◯ 4 or less
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10
- ◯ 11

12. Does your baby have a special diet?

- ◯ Yes
- ◯ No

13. If yes, tick all that apply

- ☐ Vegetarian
- ☐ Vegan
- ☐ Gluten free
- ☐ Dairy free
- ☐ Other (please specify)
- ☐ Other (please specify)

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4. Section 4. Current intake - milk & fluid

* 1. Please indicate all milk and fluids that your baby has drunk in the last 4 days:

	Has baby drunk this in the last 4 days?	How many days in the last 4 days?	How many times per day?
Breastmilk from breast			
Expressed breast milk			
Standard infant formula			
Low allergy formula			
Soy formula			
Goat's milk formula			
Standard milk (dark blue)			
Standard milk (light blue)			
Juice			
Water (not as formula- i.e. on it's own)			
Fizzy drink			
Other			

If you selected other milk, please describe, including brand

* 2. If breast feeding, how many minutes does baby usually suck for at each feed in the last 4 days (tick one)

- ◯ Not breast feeding
- ◯ 5-10 minutes
- ◯ 10-15 minutes
- ◯ 20-25 minutes
- ◯ 25-30 minutes
- ◯ 30-35 minutes
- ◯ 35-40minutes
- ◯ 40 minutes or more

* 3. For bottle/cup feeds (any milk or formula) how much does baby usually drink at each feed in the last 4 days?

- ◯ Fully breastfed
- ◯ 50-100ml
- ◯ 100-150ml
- ◯ 150-200ml
- ◯ 200-250ml
- ◯ 250-300ml

* 4. In the last 4 days, how often did your baby eat cereals/carbohydrates

	Total number of times in last 4 days	Typical amount at each feed
Rolled oats		
Breakfast cereal (e.g. cornflakes, rice bubbles, coco pops)		
Baby cereal (e.g. baby rice)		
Pasta		
Rice (e.g. brown, white. Excludes baby rice)		

Other cereals/carbohydrates (please specify total number in last 4 days and typical amount at each feed)

* 5. Please specify the type and brand of the following foods e.g. Cornflakes - Skippy or white rice - Uncle Bens

Rolled oats	
Breakfast cereal	
Baby cereal (e.g. baby rice)	
Pasta	
Rice (excludes baby rice)	
Other	

* 6. In the last 4 days, how often did your baby eat cereals/carbohydrates

	Total number of times in last 4 days	Typical amount at each feed
Weetbix		
Bread/toast		
Crackers		
Rusks		
Chapatti/Rotti		

Other cereals/carbohydrates (please specify total number in last 4 days and typical amount at each feed)

* 7. Please specify the type and brand of the following foods e.g. Wholemeal toast - homebrand or plain rice crackers - peckish or homemade

Weetbix	
Bread/toast	
Crackers	
Rusks	
Chapatti/roti	
Other	

* 8. In the last 4 days, how often did your baby eat dairy products

	Total number of times in last 4 days	Typical amount at each feed
Butter or margarine		
Cheese		
Yoghurt		
Ice-cream		
Custard		

Other dairy products (please specify total number in last 4 days and typical amount at each feed)

* 9. Please specify the type and brand of the following foods e.g. olivani lite margarine or apricot yoghurt - yoplait or homemade

Butter or margarine	
Cheese	
Yoghurt	
Ice-cream	
Custard	
Other	

* 10. In the last 4 days, how often did your baby eat meat/protein?

	Total number of times in last 4 days	Typical amount at each feed (cooked weight)
Beef (e.g. 15g mince = 1 TBSP)		
Lamb		
Pork		
Ham (e.g. 1 slice ham = 15g or 1 TBSP)		
Chicken and poultry		
Fish		
Luncheon sausage		
Eggs (e.g. 1 medium egg= 3 TBSP)		
Beans/Lentils		
Chickpea		
Tofu		

Other meat/protein foods (please specify total number in last 4 days and typical amount at each feed)

* 11. In the last 4 days, how often did your baby eat the following

	Total number of times in last 4 days	Typical amount at each feed
Dried fruit (e.g raisins)		
Popcorn		
Sweets and lollies		
Plain biscuits		
Chocolate biscuits		
Cake		
Chocolate		
Plain muesli bar		
Chocolate coated muesli bar		
Chips/crisps		
Hot chips/fries (e.g. 3 chips = 15g = 1 TBSP)		

Other (please specify total number in last 4 days and typical amount at each feed)

* 12. In the last 4 days, how often did your baby eat vegetables and fruits?

	Total number of times in last 4 days	Typical amount at each feed
Starchy (e.g. potato, kumara) e.g. 15g mashed potato = 1 TBSP		
Cruciferous (e.g broccoli, cauliflower, cabbage)		
Leafy green (e.g spinach silverbeet)		
Red and orange (e.g carrot, pumpkin, capsicum)		
Beans and peas		
Citrus (e.g. orange, mandarin)		
Berries (e.g. blueberry, strawberry)		
Melon (e.g watermelon, honeydew)		
Stone fruit (e.g. apricot, peach)		
Tropical (e.g banana, mango)		
Cucumber		
Avocado		
Apple (e.g. 1/2 small apple = 45g = 3 TBSP)		
Grapes		
Other fruit (e.g. pears)		

Other fruits and vegetables (please specify total number of times in last 4 days and typical amount at each feed)

Appendix B: Four-day Weighed Food Record (4dWFR)

ID number

Feeding Babies Study

Weighed Food Diary

To be completed by infants' primary carer(s)

Date started

DD MM YYYY

Instructions for completing food diary:

- This diary requires ***all*** the foods and fluids your infant consumes to be weighed and recorded on ***four*** non-consecutive days, including ***one*** weekend day. E.g. Monday, Wednesday, Friday, Sunday.
- Please try not to change what you give your child as a result of keeping a food diary!

Instructions for using food scales

Weigh EVERYTHING (food and liquids) in gram (g) amounts with weighing scales

tep 1: Turn on the scales

- Firstly, set scales up on a flat surface such as kitchen bench.
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g"
- If the unit is in "oz", change to "g" on the back of the scales

tep 2: Place plate or bowl on scales

- Place the EMPTY plate or bowl you intend to serve the food or liquid in on the scale.
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g" with the plate on the scale

tep 3: Weigh the plate or bowl with food (before eating)

- Add first food to the scale and record the weight in the "*Amount" column.*
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g" with the plate on the scale and first food
- Add second food to the scale and record the weight in the "*Amount" column.*
- Repeat for as needed.

tep 4: Weigh the plate or bowl with leftover food (after eating)

- Place the EMPTY plate or bowl you intend to serve the food or liquid in on the scale.
- Push the ON/ZERO key
- Ensure the display screen then appears with "0g" with the plate on the scale
- Record the weight of the first food left over in the "*weight of food leftover column"*
- Push the ON/ZERO key

- Ensure the display screen then appears with "0g" with the plate on the scale
- Record weight of second food left over in the "*weight of food leftover column"*
- Repeat as needed.

tep 5: Estimate the leftovers unable to be weighed

- For any foods that may have been spilt on the floor, or on the infant estimate as accurately as possible amounts and record in *"leftovers column" (e.g. 2tsp apple puree)*

low to estimate amounts of food and drink when you can't weigh them?

f unable to weigh and estimate the amounts, please record this in the *"weight of all meals and snacks"*

- Household measures – cups, tablespoons and teaspoons. Be specific whether it's heaped or level.
- Weights marked on packages – weights on packaged foods. E.g. ½ of a 110g tin of Watties baby food apple and pear puree.
- Bread – number and size of the slices. E.g. 1/2 slice homebrand multigrain, toast slice.
- Fruit – infants palm size used to estimate portion size. E.g. 4 green grapes, ¼ banana, ¼ granny smith apple.
- Takeaway foods – record the amount consumed and the corresponding weight of the food using the weights in the pictures of "the commonly consumed takeaway food" pictures provided

EEP IN MIND: We are not looking for a "HEALTHY" diet, we want to know what your infant eats!

XAMPLE A: How to describe recipes Day: Monday Date: 22/08/15

ood diary: Filled out by the primary carer(s) of the infant

Step 1		Step 2			Step 3	Step 4			Milk before sol
ne	Meal or snack	Name of food or drink	Brand of food or drink	Cooking method	Weight of each food or drink	Leftovers: Weight of food left over	Leftovers: Estimation of food leftover	Child fed (C) parent fed (P) or both (B)	Or Solids before m
0am al		Breastfed - 10minutes							Milk before sol
ase record dwich or st slice bread		1 slice wholegrain toast	Tip Top		25g		Almost all		
		Apple, blueberry, muesli	Heinz for baby	Microwaved	45g	13g	2 tsp		
00am ack		Banana	Bobby banana		¼ banana – palm size				
		Chocolate cake	Homemade		50g				
00pm al		4 Chicken nuggets	Tegal	Baked	70g				Solids before m
		Potato	Agria washed	Oven roasted	20g	6g	1tsp		
		Whole baby carrots frozen	Signature range	Steamed	28g		none		
0pm ack		Breastfeed – 15minutes							
0pm al		Spaghetti bolognaise	Homemade – see recipe		60g		none		Solids before m
0pm ack		Infant formula	Karicare – stage 2		200ml		none		
		Vitadol C	Karicare Vitadol C	Added to formula milk	10 drops				

Please weigh total amount of food leftover

If having fruit, and don't have scales, you can estimate using infants palm

Of total amount leftover that is unable to be weighed, please estimate each food, e.g. half banana, ¼ muesli

Record homemade recipes separately

XAMPLE B: How to record recipes

Step 1	Step 2	Step 3	Step 4	Step 5
Name of recipe	Amount of each ingredient including any water added (e.g. 3 medium carrots, 500g lean mince, 1 medium onion, 60mL water etc)	Cooking method	Proportion or recipe served to your child	Time of day
Home-made spaghetti bolognaise	300g lean beef mince (1Tbsp olive oil to brown) 50g, diced onion 50g, carrot diced 1 clove garlic, minced 60g, beef stock (Campbells) 30g tomato paste (Watties) 50g, frozen mixed vegetables (signature range) 60g water 5g white flour (homebrand) 400g dried spaghetti (budget)	Mince was shallow fried in a pan. Spaghetti was boiled in a pot	One tenth (1/10)	6pm

)ay: _____ Date: _____

ood diary: Filled out by the primary carer(s) of the infant ***Please state any supplements your infant is having e.g. Vitadol C***

Step 1		Step 2			Step 3	Step 4			Milk before solids Or Solids befor milk
ne	Meal or snack	Name of food or drink	Brand of food or drink	Cooking method	Weight of each food or drink	Leftovers: Weight of food left over	Leftovers: Estimation of food leftover	Child fed (C) parent fed (P) or both (B)	

!ecording recipes

Step 1	Step 2	Step 3	Step 4	Step 5
Name of recipe	Amount of each ingredient including any water added (e.g. 3 medium carrots, 500g lean mince, 1 medium onion, 60mL water etc)	Cooking method	Proportion or recipe served to your child	Time of day

THANK YOU!

Remember if you have any questions, please contact us. You can email or call us and we will get back to you ☺

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Appendix C: Supplementary results

Supplementary Table 1 Mean daily nutrient intakes over four days and correlations between the 4dWFR and CFFQ-1 among infants aged 9-12 months (n=95).

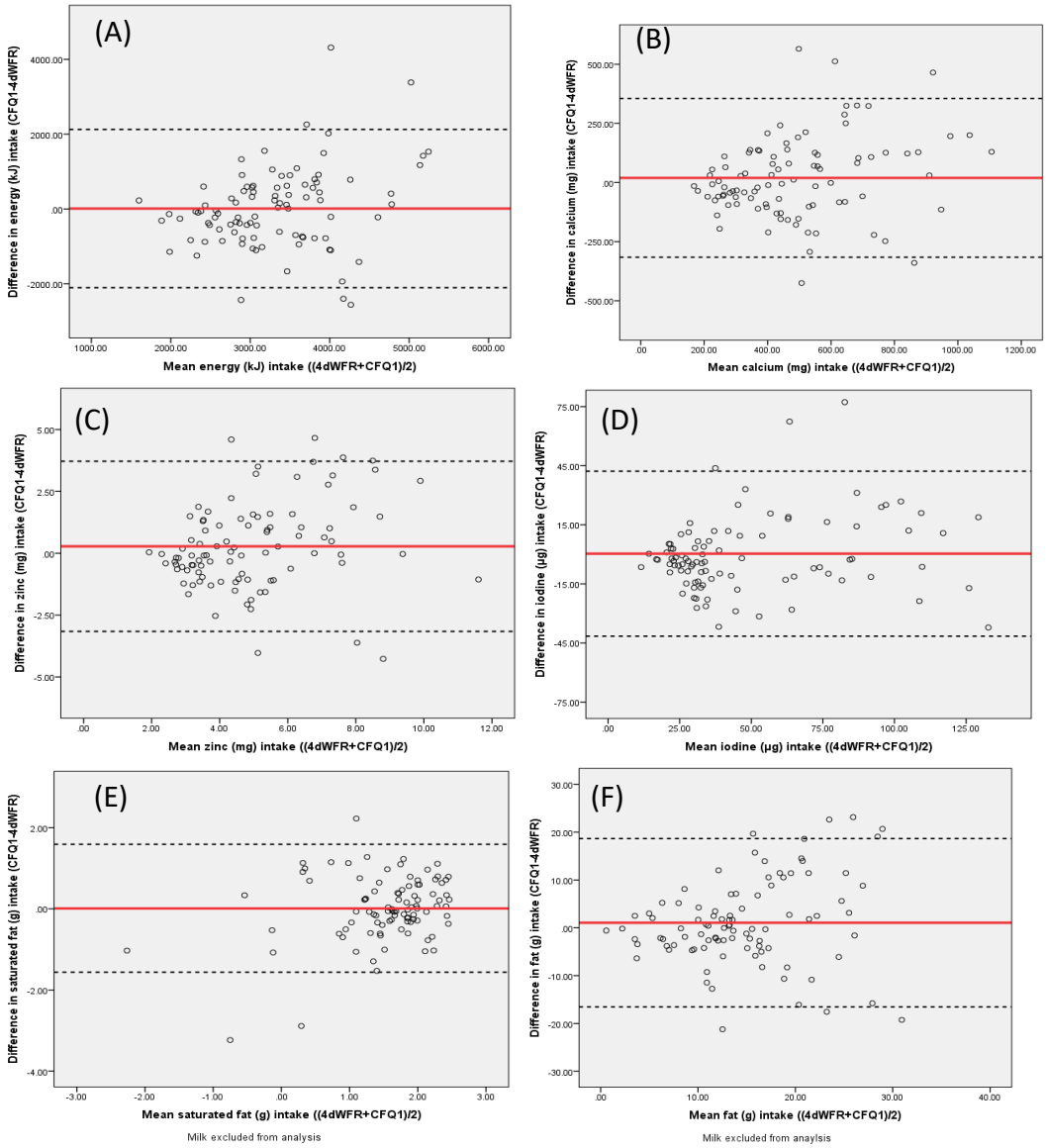
Nutrients	*4dWFR Daily intake*[a]	*CFFQ-1 Daily intake*[a]	*Mean difference (%)*[d]	*Paired t-test (p-value)*		*Correlation Coefficients* [e]	
				Unadjusted [b]	*Adjusted* [c]	*Unadjusted r* [b]	*Adjusted r* [c]
Energy (kJ)	3295 ± 810	3306 ± 1047	<1	0.92	_	0.37†	_
Protein (g)	26.6 ± 8.8	27.2 ± 10.3	2.2	0.55	0.75	0.51†	0.70†
Fat (g)	33.2 ± 8.7	37.1 ± 13.6	11.8	<0.01	0.92	0.35†	0.43†
Saturated fat (g)	13.5 ± 4.6	16.3 ± 6.2	20.5	<0.01	1.00	0.18	0.36†
Carbohydrate (g)	92.7 ± 31.2	83.6 ± 29.6	-9.8	<0.01	0.98	0.41†	0.36†
Fibre (g)	9.3 ± 4.5	6.8 ± 3.6	-26.6	<0.01	0.96	0.37†	0.24*
Vitamin E (mg)	4.8 ± 2.2	4.7 ± 2.4	<1	0.97	0.93	0.47†	0.39†
Folate (µg)	137.8 ± 74.7	115.1 ± 54.2	-16.5	<0.01	0.98	0.46†	0.57†
Potassium (mg)	1257 ± 405	1071 ± 434	-14.8	<0.01	0.92	0.50†	0.56†
Calcium (mg)	478 ± 207	498 ± 246	4.1	0.27	0.73	0.73†	0.78†
Zinc (mg)	4.8 ± 1.9	5.1 ± 2.3	5.8	0.13	0.90	0.67†	0.76†
Selenium (µg)	23.8 ± 7.8	22.8 ± 8.1	-4.5	0.28	1.00	0.27†	0.36†
Thiamin (mg)	0.6 [0.6 - 0.7]	0.6 [0.5 - 0.6]	<1	0.01	0.91	0.69†	0.64†
Riboflavin (mg)	0.8 [0.7 - 0.9]	0.7 [0.6 - 0.8]	-12.5	<0.01	0.79	0.70†	0.74†
Niacin (mg)	5.5 [5.0 - 6.0]	4.7 [4.3 - 5.2]	-14.5	<0.01	0.99	0.66†	0.65†
Vitamin C (mg)	57.3 [51.8 - 63.4]	49.7 [44.8 - 55.1]	-13.3	<0.01	0.91	0.54†	0.44†
Vitamin B_{12} (µg)	1.0 [0.9 - 1.2]	1.0 [0.8 - 1.1]	<1	0.31	0.85	0.71†	0.68†
Iodine (µg)	41.9 [37.4 - 46.9]	39.5 [34.5 - 45.3]	-5.7	0.20	0.95	0.76†	0.77†
Iron (mg)	4.6 [4.0 - 5.2]	4.3 [3.8 - 5.0]	-6.5	0.21	0.92	0.81†	0.78†

4dWFR, four-day weighed food record; CFFQ-1, First complementary food frequency questionnaire. [a] mean ± SD or geometric mean [95% CI]; [b] Unadjusted raw data with milk (breast milk and formula) included; [c] Adjusted for energy intake (milk included); [d]Mean difference calculated as CFFQ-1-4dWFR/4dWFR; [e]Pearson's Correlation Coefficients; † *p*=<0.01, significant difference (2-tailed); * *p*=<0.05, significant difference (2-tailed).

Supplementary Table 2 Cross-classification by tertiles of nutrient intakes and weighted kappa based on the 4dWFR and CFFQ-1 among infants aged 9-12 months (n=95). [a]

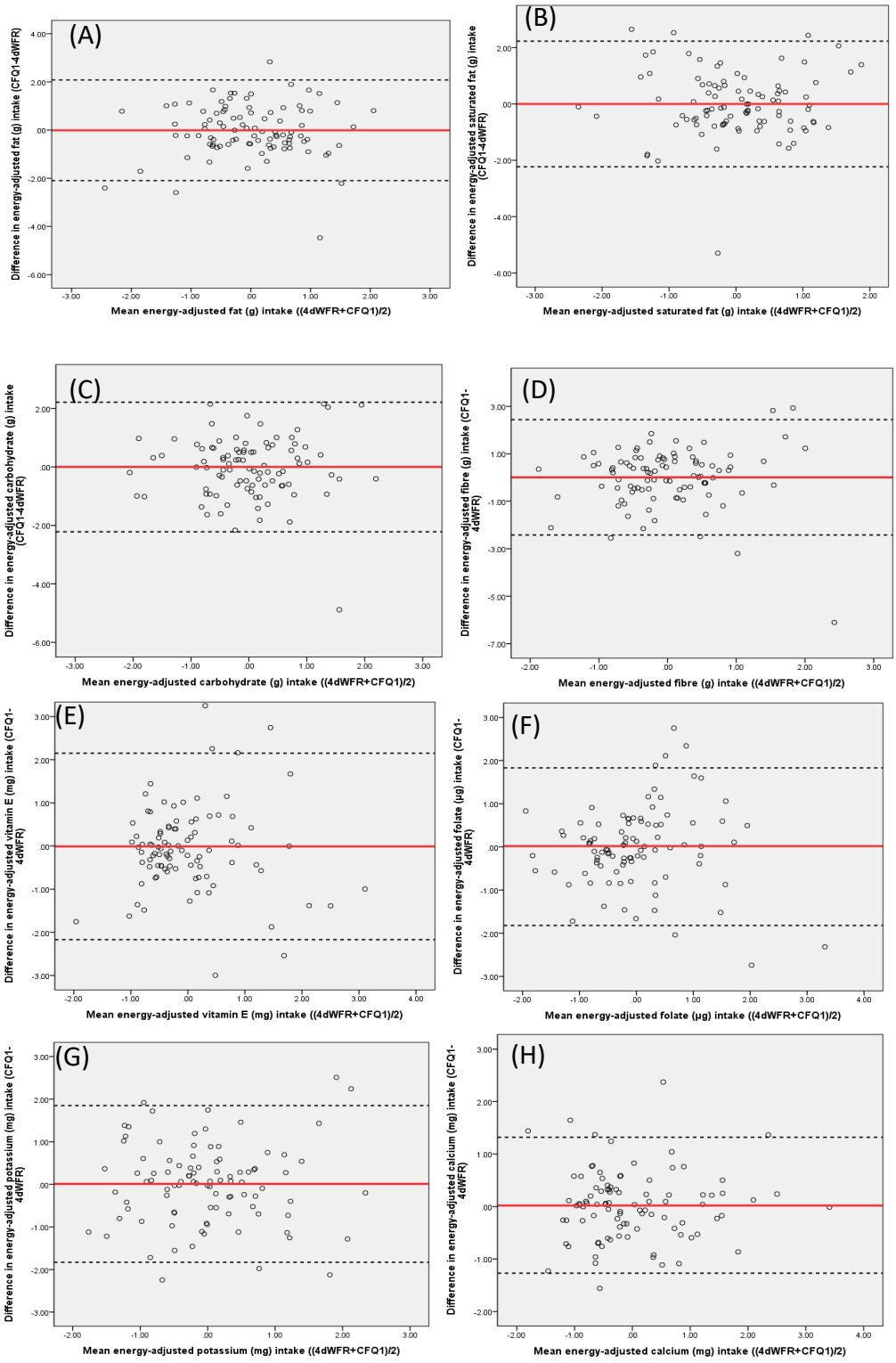
	Unadjusted [b]			*Adjusted* [c]		
Nutrients	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*
Energy (kJ)	44.2	10.5	0.25	_	_	_
Protein (g)	52.6	5.3	0.41	62.1	4.2	0.53
Fat (g)	52.6	10.5	0.34	49.5	9.5	0.33
Saturated fat (g)*	43.2	14.7	0.19	49.5	8.4	0.34
Carbohydrate (g)	55.8	9.5	0.39	43.2	11.6	0.23
Fibre (g)	46.3	9.5	0.29	39.0	12.6	0.18
Vitamin E (mg)	49.5	8.4	0.34	44.2	9.5	0.26
Folate (µg)	50.5	12.6	0.30	60.0	6.3	0.48
Potassium (mg)	45.3	8.4	0.29	64.2	7.4	0.52
Calcium (mg)	65.3	2.1	0.58	66.3	2.1	0.60
Zinc (mg)	60.0	4.2	0.50	62.1	3.2	0.54
Selenium (µg)*	39.0	12.6	0.17	46.3	13.7	0.24
Thiamin (mg)	57.9	3.2	0.49	51.6	6.3	0.38
Riboflavin (mg)	54.7	4.2	0.44	63.2	3.2	0.55
Niacin (mg)	57.9	3.2	0.49	51.6	5.3	0.40
Vitamin C (mg)	60.0	5.3	0.49	60.0	12.6	0.41
Vitamin B_{12} (µg)	61.1	4.2	0.52	67.4	3.2	0.60
Iodine (µg)	60.0	4.2	0.51	63.2	1.1	0.58
Iron (mg)	67.4	2.1	0.61	68.4	3.2	0.61

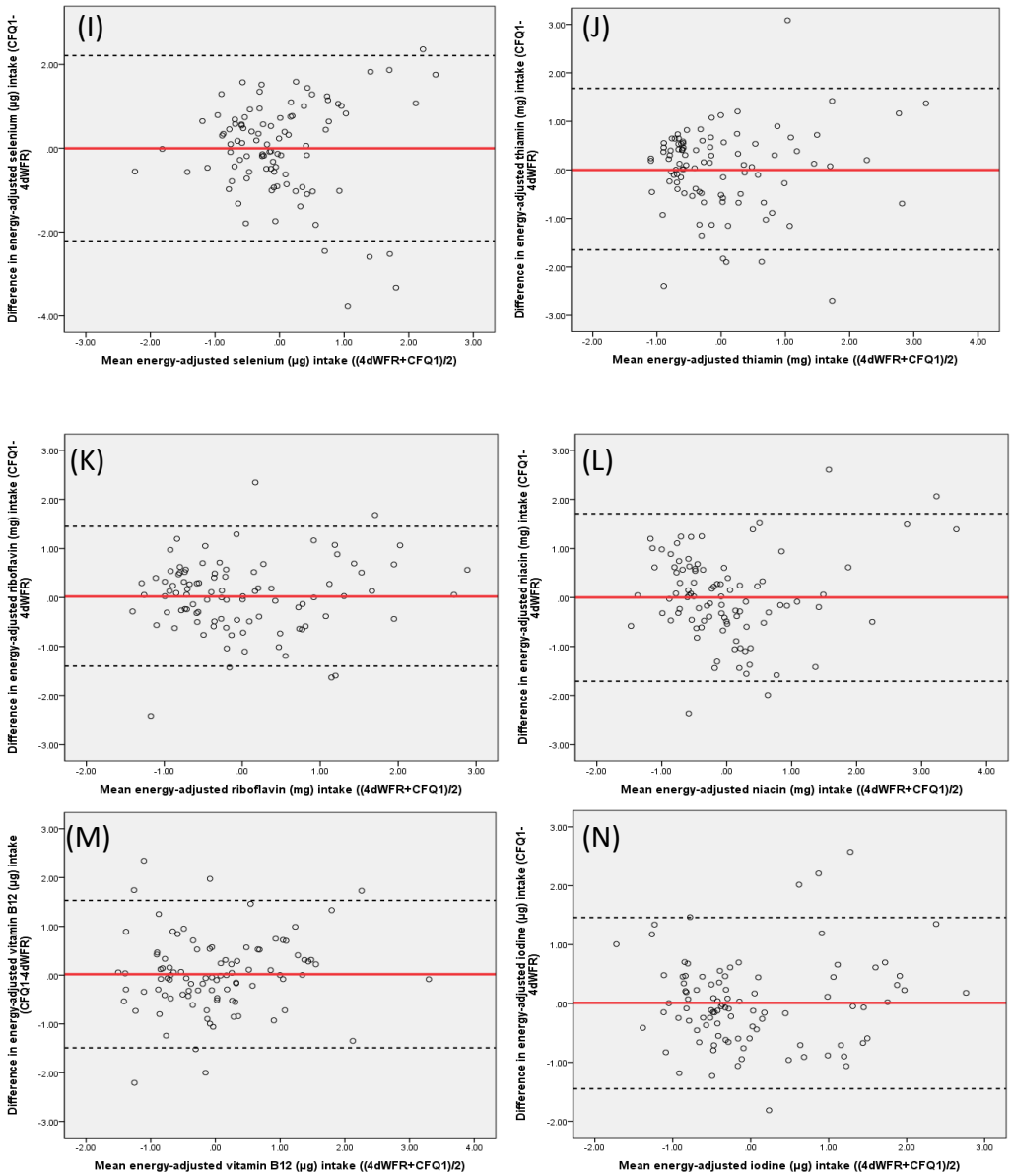
4dWFR, four-day weighed food record; CFFQ-1, First complementary food frequency questionnaire. [a] All data includes milk; [b] Unadjusted raw dietary data; [c] Adjusted for energy intake; *Not significant $p>0.05$ (Pearson chi-square, 2-sided).
Note: Participants were in tertiles, 2 groups of 32 participants and 1 group of 31



Supplementary Figure 1. Bland-Altman plots of the agreement between intakes for nutrients for (A) energy, (B) calcium, (C) zinc, (D) iodine, (E) saturated fat, and (F) total fat (n=95).

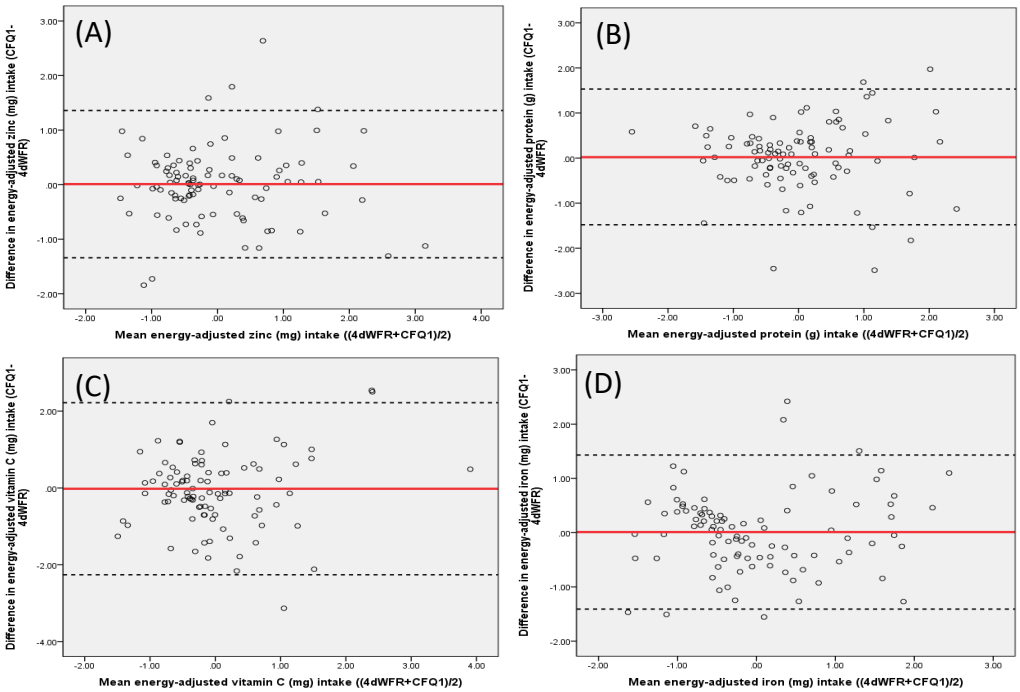
A solid line representing the mean difference between the two dietary methods and dashed lines representing the limits of agreement (LOA = mean difference ± 1.96 SD).


(A)
Difference in energy-adjusted fat (g) intake (CFQ1-4dWFR)
Mean energy-adjusted fat (g) intake ((4dWFR+CFQ1)/2)
(B)
Difference in energy-adjusted saturated fat (g) intake (CFQ1-4dWFR)
Mean energy-adjusted saturated fat (g) intake ((4dWFR+CFQ1)/2)
(C)
Difference in energy-adjusted carbohydrate (g) intake (CFQ1-4dWFR)
Mean energy-adjusted carbohydrate (g) intake ((4dWFR+CFQ1)/2)
(D)
Difference in energy-adjusted fibre (g) intake (CFQ1-4dWFR)
Mean energy-adjusted fibre (g) intake ((4dWFR+CFQ1)/2)
(E)
Difference in energy-adjusted vitamin E (mg) intake (CFQ1-4dWFR)
Mean energy-adjusted vitamin E (mg) intake ((4dWFR+CFQ1)/2)
(F)
Difference in energy-adjusted folate (µg) intake (CFQ1-4dWFR)
Mean energy-adjusted folate (µg) intake ((4dWFR+CFQ1)/2)
(G)
Difference in energy-adjusted potassium (mg) intake (CFQ1-4dWFR)
Mean energy-adjusted potassium (mg) intake ((4dWFR+CFQ1)/2)
(H)
Difference in energy-adjusted calcium (mg) intake (CFQ1-4dWFR)
Mean energy-adjusted calcium (mg) intake ((4dWFR+CFQ1)/2)



Supplementary Figure 2. Bland-Altman plots of the agreement between intakes for energy-adjusted nutrients for (A) fat, (B) saturated fat, (C) carbohydrate, (D) fibre, (E) vitamin E, (F) folate, (G) potassium, (H) calcium, (I) selenium, (J) thiamin, (K) riboflavin, (L) niacin, (M) vitamin B_{12} and (N) iodine (n=95).

A solid line representing the mean difference between the two dietary methods and dashed lines representing the limits of agreement (LOA = mean difference ± 1.96 SD).



Supplementary Figure 3. Examples of Bland-Altman plots of the agreement between intakes for energy-adjusted nutrients for (A) zinc, (B) protein, (C) vitamin C and (D) iron (n=95).

A solid line representing the mean difference between the two dietary methods and dashed lines representing the limits of agreement (LOA = mean difference ± 1.96 SD).

Supplementary Table 3 Bland-Altman statistics comparing nutrient intakes from the 4dWFR and CFFQ-1 among infants aged 9-12 months (n=95).

	Milk included [a]			*Milk not included* [b]		
Nutrients	*Mean difference* [c]	*LOA*ǂ	*Slope of bias (B)*	*Mean difference* [c]	*LOA*ǂ	*Slope of bias (B)*
Energy (kJ)	11.42	2126.05, -2103.25	0.38*	_	_	_
Protein (g)	0.59	19.24, -18.06	0.21	-0.53	16.38, -17.45	0.20
Fat (g)	_	_	_	1.06	18.66, -16.53	0.29*
Saturated fat (g)	_	_	_	0.01	1.59, -1.56	0.28*
Vitamin E (mg)	-0.01	4.62, -4.64	0.14	_	_	_
Calcium (mg)	19.65	355.26, -315.95	0.20*	_	_	_
Zinc (mg)	0.28	3.72, -3.16	0.22*	-0.18	2.42, -2.77	0.14
Selenium (µg)	-1.08	17.74, -19.90	0.07	_	_	_
Vitamin B_{12} (µg)	-0.06	1.09, -1.22	0.01	-0.09	1.05, -1.23	-0.13
Iodine (µg)	0.34	42.25, -41.56	0.17*	_	_	_

4dWFR, four-day weighed food record; CFFQ-1, First complementary food frequency questionnaire; [a] Unadjusted raw dietary data with breast milk and formula intake included; [b] Excludes breast milk and formula intake from analysis; [c] Only nutrients with mean differences of $p>0.05$ were included in Bland-Altman analysis; *Regression p-value <0.05, significant difference (2-tailed); B=unstandardized coefficient; ǂ 95% confidence interval (upper, lower)

Supplementary Table 4 Bland-Altman statistics comparing energy-adjusted nutrient intakes from the 4dWFR and CFFQ-1 among infants aged 9-12 months (n=95). [a]

Nutrients	*Mean difference*	*LOA[ł]*	*Slope of bias (B)*
Protein (g)	0.02	1.531, -1.481	0.01*
Fat (g)	-0.01	2.082, -2.104	0.01*
Saturated fat (g)*	0.00	2.227, -2.228	0.01*
Carbohydrate (g)	0.00	2.212, -2.217	0.01*
Fibre (g)	0.01	2.435, -2.424	0.01*
Vitamin E (mg)	-0.01	2.151, -2.170	0.01*
Folate (µg)	0.00	1.827, -1.824	<0.01*
Potassium (mg)	0.01	2.489, -1.833	0.01*
Calcium (mg)	0.02	1.853, -1.270	0.01*
Zinc (mg)	0.01	1.317, -1.339	<0.01*
Selenium (µg)*	0.00	1.356, -2.209	0.01*
Thiamin (mg)	0.01	2.209, -1.652	0.05*
Riboflavin (mg)	0.02	1.673, -1.399	0.06*
Niacin (mg)	0.00	1.439, -1.631	0.09*
Vitamin C (mg)	-0.01	1.634, -2.080	0.15*
Vitamin B_{12} (µg)	0.02	2.054, -1.558	0.09*
Iodine (µg)	0.00	1.588, -1.329	0.06*
Iron (mg)	0.01	1.338, -1.300	0.07*

4dWFR, four-day weighed food record; CFFQ-1, First complementary food frequency questionnaire; [a] Energy adjusted dietary data with breast milk and formula intake included; *****Regression *p*-value <0.05, significant difference (2-tailed); B=unstandardized coefficient; *ł* 95% confidence interval (upper, lower)

Supplementary Table 5 Mean daily nutrient intakes over four days and correlations between the CFFQ-1 and CFFQ-2 among infants aged 9-12 months (n=93).

Nutrients	*CFFQ-1 Daily intake*[a]	*CFFQ-2 Daily intake*[a]	*Mean difference (%)*[d]	*Paired t-test (p-value)*		*Correlation Coefficients* [e]	
				Unadjusted [b]	*Adjusted* [c]	*Unadjusted r* [b]	*Adjusted r* [c]
Energy (kJ)	3284 ± 1047	3239 ± 905	-1.4	0.61	_	0.62†	_
Protein (g)	27.0 ± 10.5	28.7 ± 11.3	6.4	0.07	0.93	0.66†	0.68†
Fat (g)	36.9 ± 13.4	35.6 ± 9.9	-3.6	0.22	0.80	0.63†	0.63†
Saturated fat (g)	16.2 ± 6.1	15.7 ± 4.6	-2.8	0.36	0.69	0.64†	0.69†
Carbohydrate (g)	83.0 ± 29.8	81.3 ± 28.2	-2.1	0.51	0.90	0.63†	0.57†
Fibre (g)	6.8 ± 3.6	7.1 ± 4.0	4.5	0.37	0.57	0.63†	0.57†
Vitamin E (mg)	4.7 ± 2.4	4.5 ± 2.0	-4.2	0.24	0.74	0.73†	0.75†
Folate (µg)	114.9 ± 53.1	131.2 ± 90.8	14.2	0.07	0.92	0.40†	0.34†
Potassium (mg)	1066 ± 439	1087 ± 440	2.0	0.62	0.93	0.58†	0.53†
Calcium (mg)	491 ± 247	506 ± 251	3.0	0.40	0.82	0.76†	0.77†
Zinc (mg)	5.1 ± 2.3	5.1 ± 2.1	1.3	0.69	0.84	0.76†	0.80†
Selenium (µg)	22.8 ± 8.2	23.4 ± 10.5	2.9	0.53	0.98	0.45†	0.45†
Thiamin (mg)	0.5 [0.5 - 0.6]	0.6 [0.5 - 0.7]	20.0	0.01	0.99	0.67†	0.58†
Riboflavin (mg)	0.7 [0.6 - 0.8]	0.8 [0.7 - 0.9]	14.3	<0.01	0.87	0.75†	0.72†
Niacin (mg)	4.7 [4.2 - 5.2]	4.7 [4.3 - 5.2]	<1	0.70	0.92	0.71†	0.66†
Vitamin C (mg)	49.0 [44.2 - 54.3]	47.3 [42.5 - 52.7]	-3.5	0.43	0.55	0.65†	0.51†
Vitamin B_{12} (µg)	0.9 [0.8 - 1.1]	1.1 [0.9 - 1.2]	22.2	0.02	0.98	0.82†	0.69†
Iodine (µg)	39.4 [34.3 - 45.1]	41.0 [35.9 - 46.7]	4.1	0.41	0.10	0.75†	0.72†
Iron (mg)	4.3 [3.7 - 4.9]	4.8 [4.2 - 5.5]	11.6	0.01	0.73	0.80†	0.74†

CFFQ-1, First complementary food frequency questionnaire; CFFQ-2, Second complementary food frequency questionnaire. [a] mean ± SD or geometric mean [95% CI]; [b] Unadjusted raw dietary data with milk (breast milk and formula) intake included; [c] Adjusted for energy intake (milk included); [d] Mean difference calculated as CFFQ-2-CFFQ-1/CFFQ-1; [e] Pearson's Correlation Coefficients; † p=<0.01, significant difference (2-tailed).

Supplementary Table 6 Cross-classification by tertiles of nutrient intakes and weighted kappa based on the CFFQ-1 and CFFQ-2 among infants aged 9-12 months (n=93).

	Unadjusted [b]			*Adjusted* [c]		
Nutrients	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*	*Correctly classified into the same tertile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*
Energy (kJ)	55.9	9.7	0.40	_	_	_
Protein (g)	59.1	8.6	0.44	66.7	2.2	0.60
Fat (g)	40.9	6.5	0.25	57.0	4.3	0.46
Saturated fat (g)	47.3	8.6	0.30	71.0	5.4	0.61
Carbohydrate (g)	60.2	7.5	0.46	52.7	6.5	0.39
Fibre (g)	52.7	8.6	0.37	59.1	9.7	0.42
Vitamin E (mg)	59.1	4.3	0.49	59.1	5.4	0.48
Folate (µg)	57.0	7.5	0.43	48.4	7.5	0.33
Potassium (mg)	58.1	8.6	0.43	64.5	4.3	0.55
Calcium (mg)	66.7	4.3	0.57	63.4	4.3	0.54
Zinc (mg)	71.0	4.3	0.62	63.4	3.2	0.55
Selenium (µg)	54.8	6.5	0.42	47.3	6.5	0.33
Thiamin (mg)	55.9	5.4	0.44	55.9	5.4	0.44
Riboflavin (mg)	63.4	4.3	0.54	66.7	2.2	0.60
Niacin (mg)	63.4	8.6	0.49	50.5	6.5	0.37
Vitamin C (mg)	64.5	5.4	0.54	57.0	6.5	0.44
Vitamin B_{12} (µg)	72.0	2.2	0.66	63.4	4.3	0.54
Iodine (µg)	59.1	2.2	0.51	64.5	3.2	0.56
Iron (mg)	71.0	3.2	0.63	65.6	3.2	0.57

CFFQ-1, First complementary food frequency questionnaire; CFFQ-2, Second complementary food frequency questionnaire.
[a] All data includes milk; [b] Unadjusted raw dietary data; [c] Adjusted for energy intake;

NOTE: Participants were in tertiles, 3 groups of 31

Supplementary Table 7 Weight (g) conversion used for each food item from the CFFQ used for statistical analysis.

	Food item	*Measure*	*Weight (g)*
Cereals and carbohydrates			
	Rolled oats	1 Tbsp	15.4
	Breakfast cereal	1 Tbsp	4
	Baby cereal	1 Tbsp	15
	Pasta	1 Tbsp	9.2
	Rice	1 Tbsp	10
	Weet-Bix	1	15
	Bread	1	36
	Crackers	1	2.7
	Rusks	1	8
	Chapatti	1	26
Dairy products			
	Butter/margarine	1 Tbsp	14
	Cheese	1 Tbsp	15
	Yoghurt	1 Tbsp	15.4
	Ice-cream	1 Tbsp	8
	Custard	1 Tbsp	16.6
	Milk	1 Tbsp	15.2
Meat/protein			
	Beef	1 Tbsp	15
	Lamb	1 Tbsp	15
	Pork	1 Tbsp	15
	Ham	1 Tbsp	7.4
	Chicken	1 Tbsp	15
	Fish	1 Tbsp	15
	Luncheon	1 Tbsp	15
	Egg	1 Tbsp	15
	Beans/lentils	1 Tbsp	15
	Chickpeas	1 Tbsp	10.2
	Tofu	1 Tbsp	15
Occasional foods			
	Dried fruit	1 Tbsp	10
	Popcorn	1 Tbsp	0.7
	Lollies	1 Tbsp	20
	Plain biscuits	1	10
	Chocolate biscuits	1	15
	Cake	1 Tbsp	8
	Chocolate	1 Tbsp	15.6
	Plain muesli bar	1 Tbsp	15

	Chocolate muesli bar	1 Tbsp	15
	Chips/crisps	1 Tbsp	3.1
	Hot chips	1 Tbsp	8.3
Vegetables and fruits			
	Starchy	1 Tbsp	15
	Cruciferous	1 Tbsp	11.5
	Leafy green	1 Tbsp	6.8
	Red and orange	1 Tbsp	9.8
	Beans	1 Tbsp	11
	Citrus	1 Tbsp	15
	Berries	1 Tbsp	15.8
	Melon	1 Tbsp	15
	Stone fruit	1 Tbsp	12.4
	Tropical	1 Tbsp	15
	Cucumber	1 Tbsp	15
	Avocado	1 Tbsp	15
	Apple	1 Tbsp	15
	Grapes	1 Tbsp	15
	Other	1 Tbsp	15

Abbreviations: CFFQ, Complementary food frequency questionnaire; Tbsp, Tablespoon

Appendix D: Participant materials

Consent form

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

Feeding Babies study

PARTICIPANT CONSENT FORM

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree for my baby and I to participate in this study under the conditions set out in the Information Sheet.

Individual consent

Printed signature ..... Date: .....

Parent/Caregiver
Full Name - printed .....

Baby
Full Name - printed .....

Would you like to be contacted occasionally regarding research studies taking place at Massey University? Please delete as appropriate.

Yes / No

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

Feeding Babies study

INFORMATION SHEET

We would like to invite you to take part in the Feeding Babies study, which aims to develop and validate a tool to assess nutrient intake in infants aged between 9 and 12 months. This study is being led by Amy Judd and Owen Mugridge, supervised by Dr Cath Conlon and Dr Kathryn Beck, School of Food and Nutrition, College of Health, Massey University.

Please read this Information Sheet carefully before deciding whether or not to participate.

Researchers Introduction

The lead researchers for this study are Amy Judd, Dr Cath Conlon and Owen Mugridge.

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Why is this research important?

It is well known that a baby's diet is important for their early growth and development. To assess a baby's diet there are a range of dietary assessment methods available. Some of the traditional dietary assessment methods are time consuming and not appropriate to the infant population. Therefore, the aim of this study is to validate a new quick and easy dietary assessment tool, (an online questionnaire) against the traditional gold standard method (a food diary) to assess its validity and accuracy to assess nutrient intake.

Participant Identification and Recruitment

We are looking to recruit 100 mothers and their 9-12 month old infants.

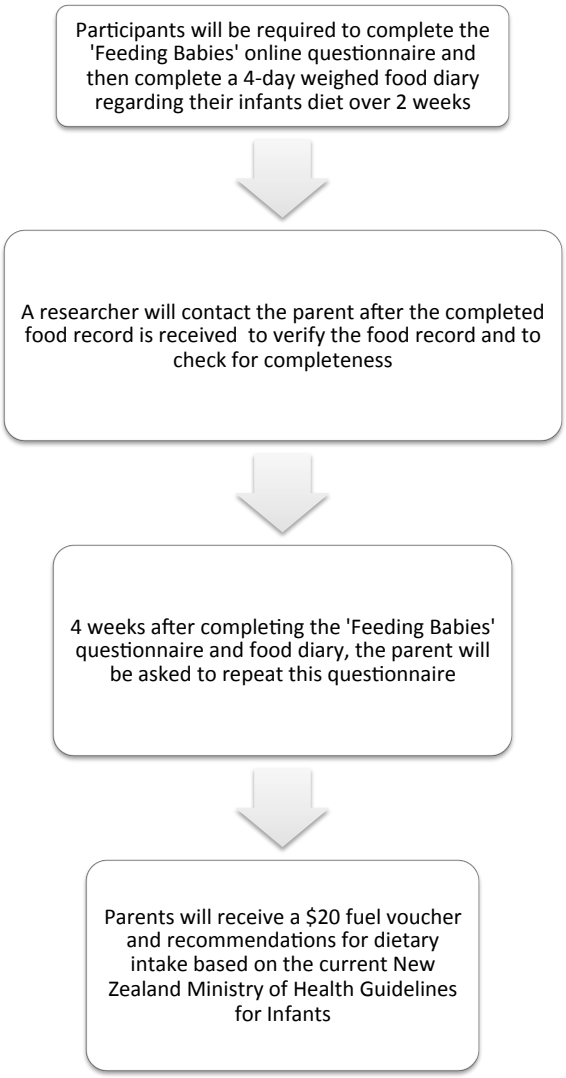
What are the benefits and risks of taking part in this study?

Participants will receive general feedback on recommendations for dietary intake based on the current New Zealand Ministry of Health guidelines. If participants do not have their own set of food scales, participants will be provided with a set to complete their infants weighed food diary. There is minimal risk associated with participating in this study. All mothers who participate will receive a complimentary $20 voucher.

Project Procedures

Participants will be required to complete the following:

Feeding Babies Study flow diagram:



Data Management

How will the data be used?

The data will be used for the purposes of this study. Results of this study may be published or presented at conferences or seminars; however, no individual will be identifiable. Only the investigators of the study will have access to personal information and this will be kept secure and strictly confidential.

How will the data be stored?
Participants will be identified only by a unique study identification code and all data forms will use this code. The data forms will be stored in a locked filing cabinet in the Human Nutrition Research Unit, Albany Campus, Massey University. The electronic data will be stored on computers, which are protected by passwords, in locked offices of the Human Nutrition Research Unit.

How will the data be disposed of?
At the end of this study the list of participants and their study identification codes will be disposed of. Information collected from Survey Monkey will be downloaded and online files deleted. Any raw data on which the results of the project depend will be retained in secure storage for 16 years, after which time it will be destroyed.

How will I access a summary of the project findings?
A summary of the project findings will be available to all study participants and you will be sent this information by email.

Participant's Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study at any time;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded.

If you have any questions about this project or would like more information please contact Amy Judd by email (A.L.Judd@massey.ac.nz) or phone ([redacted]).

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application (NOR 15/061). If you have any concerns about the conduct of this research, please contact Dr Andrew Chrystall, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800 x 43317, email humanethicsnorth@massey.ac.nz.

"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researchers named above are responsible for the ethical conduct of this research.

Thank you for your consideration regarding participation in this study! ☺

Demographic questionnaire

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Feeding Babies study

Demographic questionnaire

1. Primary caregiver name: _____
2. Primary email address: _____
3. Contact telephone number: _____
4. Please tick which best describes your relationship with the baby participating in this study
   a. □ Mother □ Father □ Primary caregiver
   (please describe your relationship)_____
5. What is your baby's gender? Male / Female (please circle)
6. What is your baby's date of birth? (DD/MM/YYYY) _____
7. How many <u>other</u> children do you have? _____
8. To which ethnic group(s) do you identify with? *Please tick all the boxes which apply*

   □ European
   □ Māori
   □ Pacific peoples
   □ Asian
   □ Middle Eastern/Latin American/African
   □ Other ethnicity
   If other, please state:_____

9. If Māori, please provide your tribal affiliations _____
10. Which ethnic group(s) does your baby identify with? *Please tick all the boxes which apply*

    □ European
    □ Māori
    □ Pacific peoples
    □ Asian
    □ Middle Eastern/Latin American/African
    □ Other ethnicity
    If other, please state: _____

10. At how many weeks gestation was your child born? _____
11. Does your baby have any medical conditions?
    □ Yes □ No
    If yes, please specify _____

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