Dietary sugar intake from complementary foods: a cross-sectional study describing total, free and added sugar intake of infants living in New Zealand

A Thesis presented in the partial fulfilment of the requirements for the degree of

Master of Science

In

Nutrition and Dietetics

Massey University, Albany

New Zealand

Annabelle Malone

2021

Abstract

Background: Complementary feeding is introduced at around six months of age when breast milk alone is no longer sufficient to meet the nutritional requirements of an infant. Additional foods and liquids are introduced alongside breast milk to bridge the gap and fulfil nutritional requirements. The types of foods introduced during complementary feeding influence the eating habits and behaviours of the infants and thus can play a role in future health outcomes. Excess total, free, and added sugar intake during infancy can increase the risk of dental caries, nutrient displacement, undesirable weight gain and the development of unhealthy eating habits. Infant feeding recommendations advise against added sugars, honey or sweeteners during the complementary feeding stage as they provide no nutritional benefit. Furthermore they may accustom an infant to sweet tasting foods. There are limited studies assessing total, free and added sugar intake of New Zealand infants. The quantity of sugar from various food sources, feeding practices (baby led weaning and traditional spoon feeding), frequency of pouch use and non-commercial/commercial infant food, require further investigation to better understand where, what and how sugar intake occurs in New Zealand infants.

Aim: To investigate the quantity of total, free and added sugars in the diets of infants from the First Foods study in New Zealand and explore the food sources, feeding practices and frequency of pouch use contributing to sugar intake during complementary feeding.

Methods: An observational cross-sectional study design was used. Two 24hr diet recalls were conducted on non-consecutive days with caregivers of 211 infants (aged between 7 to 10 months) across Auckland and Dunedin. Descriptive analyses were carried out using excel and SPSS to determine, energy and macronutrient intakes, total/free/added sugar intake by food group, feeding practice, pouch use and non-commercial/commercial infant food. Feeding practices included baby led weaning, partial baby led weaning and traditional spoon feeding. Baby led weaning infants were defined as infants who are fed finger foods as opposed to pureed or mashed foods.
Inferential analyses were run for feeding practice and pouch use to determine whether there was a difference in sugar intake between the groups.

Results: Infants median total, free and added sugar intake from complementary foods was 15.8g/day. 0.5g/day and 0.2g/day, respectively. Total sugar contributed to 18.4% of the total energy intake from all nutrient sources. Infants consumed sugars from 32 defined food groups. Of these food groups, custards (9.87g), sweet pouches (9.71g), yoghurt with fruit (7.76g), fruit (4.98g), and sweetened breakfast (3.56g) contributed the most to total sugar intake. All food groups contributed less than 2g/day of free and added sugar, excluding custards (5.58g) and yoghurt with fruit (2.18g). There was no significant difference in total sugar intake between feeding practices. Free and added sugar were significantly different between feeding practices as determined through the Kruskal-Wallis test (P values= 0.035 and 0.003). Free sugar intake was significantly higher in infants following traditional spoon feeding compared to infants following baby led weaning. Added sugar intake was also significantly higher in infants following traditional spoon feeding and partial baby led weaning compared to infants following baby led weaning. Relationships between sugar intake and feeding practice were identified using the Dunn-Bonferroni post hoc test. The same significance tests were run for frequency of pouch use and sugar intake. Infants categorised as frequent pouch users consumed the highest values of total, free and added sugar (19.89g/d, 1.59g/d and 1.19g/d) and intakes of total, free and added sugar were significantly different between differing pouch use groups (P values= 0.001, 0.0 and 0.018). Non-pouch users had a significantly lower intake of total, free and added sugar compared to frequent pouch users. Non-commercial foods contributed 6.33g/d more total sugar than commercial food; free and added sugar intakes were $\leq$0.25g for commercial, mixed, and non-commercial foods.

Conclusion: The quantity of total, free and added sugars in the diets of infants from the First Foods study was minimal regardless of feeding method, pouch use and food form. The majority of the foods eaten by the infants did not contain free sugar. Intake of added sugar from custard and yoghurt with fruit was over 2g per day. Food groups that contributed the most to total sugar intake were fruit-based. There were no significant relationships between feeding practice (Baby-led weaning, partial baby-led weaning and traditional spoon feeding) and sugar intake. Infants who were categorised as frequent pouch users had the highest intake of total, free and added sugar compared to infants in the moderate and non-pouch user groups. Parents should be encouraged to choose foods for their infants that are low in total, free and added sugar and to expose their infants to bitter-tasting foods. As current practices show that parents are exposing their infants to minimal sugars, there is no need to change the way infants are fed in New Zealand in relation to sugar intake.

Keywords: infant, complementary feeding, sugar intake, food sources, feeding practices, pouch use

Acknowledgements

First, I would like to thank all the parents and caregivers involved in this study, whom this research would not be possible without. It was amazing meeting you and your little ones on visits. I thank you for your cooperation, patience and time spent giving every minor detail of your infants diet.

To my academic supervisors, Cathryn Conlon, Pamela von Hurst and Kathryn Beck who guided me through- Thank you. Your guidance was truly amazing. You were patient, and you pushed me through in times when I needed it most. The progression of this thesis reflects your continuous feedback and support.

To the Auckland first foods team, you have been a big part of my journey this year and I can’t thank you enough for your encouragement and support. I am so grateful to be a part of such a wonderful, hardworking team.

To my family and friends who helped me to stay positive and motivated during this year. In particular my mother; Pauline Malone. Thank you for your continuous encouragement and reassurance throughout my academic journey.

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Symbols

Abbreviation or Symbol	Definition
AI	Adequate intake
BLW	Baby led weaning
BMI	Body Mass Index
CACFs	Commercially available complementary foods
CVD	Cardiovascular disease
Et al.	And others
g	Grams
kg	Kilograms
kJ	Kilojoules
MoH	Ministry of Health
MSc	Master of Science
NRV	Nutrient reference value
NZ	New Zealand
RACC	Reference amounts customarily consumed
TSP	Traditional spoon feeding
T2DM	Type two diabetes mellitus
WHO	World Health Organization
%	Percentage
<	Less than
=	Equal to
>	Greater than
±	Plus-minus

Chapter 1: Introduction

1.1. Background

From birth to six months, it is recommended that an infant is exclusively breast fed followed by the addition of solid foods until at least twelve months (Ministry of Health, 2021). The term “exclusive breast feeding” refers to purveying breast milk and any prescribed medications only (Ministry of Health, 2021). Breast milk is a complete nutrition source for the first six months of life and provides additional benefits such as protection against infection and aiding physical and mental development (Martin, Ling, & Blackburn, 2016; Ministry of Health, 2021). Given the combination of nutritive and non-nutritive benefits, breast milk is documented as the ideal source of nutrition for infants (Ministry of Health, 2021). Breast feeding is not always possible, suitable, or adequate on its own, in which case infant formula is advised as the only suitable substitute (Martin et al., 2016; Ministry of Health, 2021). Breast milk contains carbohydrate, which is predominantly lactose, a sweet naturally occurring milk sugar. Lactose is an important source of energy in an infant’s diet.

From six months an infant should gradually expand to a diet consisting of various foods. Around six months, an infant will no longer meet its complete nutritional requirements from breast milk or formula milk (Ministry of Health, 2021). Following this timeframe, additional foods known as complementary foods are fed alongside breast milk or formula milk to support health and growth (Ministry of Health, 2021). This journey is the most significant change in nutrition in human life, playing an essential role in shaping eating habits and behaviour’s (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Mis, et al., 2017).

Infants are at high risk of undernutrition. It is crucial that energy needs are met to support the needs of the growing infant. Additional energy is derived from complementary foods, which should cover the nutritional gap and meet energy requirements with breast milk/formula (World Health Organization, 2009). However, complementary foods which are high in total sugar, free or added sugar have the potential to result in poor health consequences when consumed in excessive amounts (World Health Organization, 2015a). These types of sugars are defined in Table 1.1. Such consequences include nutrient displacement, undesirable weight gain and the development of dental caries (DiNicolantonio & Berger, 2016; World Health Organization, 2015b). Within New Zealand, the percentage of children aged 5yrs with dental caries was 41% in 2018 (Environmental Health Indicators New Zealand, 2020). Although dental health is affected by other factors such as fluoride in toothpaste and brushing teeth, sugar intake is a significant contributor to tooth decay and thus should be a focal point for interventions around oral health (Environmental Health Indicators New Zealand, 2020). Poor health consequences of excessive sugar intake during infancy are largely a result of the eating habits and behaviours developed during this period that have been carried through into childhood/adulthood (Rose, Birch, & Savage, 2017). An example of this can be seen in the associated long term risk factors, namely cardiovascular disease and type two diabetes (T2DM). Diabetes development stems from poor long-term eating habits, high sugar intake and genetics (Basu, Yoffe, Hills, & Lustig, 2013). The prevalence of Individuals in New Zealand (NZ) diagnosed with TD2M is 250,000 persons (around 1 in 20 people) (Ministry of Health, 2020c). Furthermore, the incidence of T2DM among children is increasing at alarming rates, which is concerning as morbidity and mortality increases with an earlier onset (nz, 2018). Like many non-communicable diseases, preventing or delaying the onset of T2DM is vital in reducing the burden of diabetes complications (nz, 2018).

Table 1.1. Definitions and descriptions of types of sugars

Type of sugar	Definition
Total sugar	Total sugar refer to the total sugar content of the food product, which may be composed of intrinsic sugars incorporated within the structure of intact fruit and vegetables; sugars from milk (lactose and galactose); and all additional monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and fruit juices. (Ministry of Health, 2020b)
Added sugar	The term “added sugar” is used prominently within the United States and within some other countries defined according to the United States Food and Drug Administration (US FDA) definition: “sugars that are either added during the processing of foods, or are packaged as such, and include sugars (free, mono- and disaccharides), sugars from syrups and honey, and sugars from concentrated fruit or vegetable juices that are in excess of what would be expected from the same volume of 100 percent fruit or vegetable juices of the same type. The definition excludes fruit or vegetable juice concentrated from 100 percent fruit juice that is sold to consumers (e.g. frozen 100 percent fruit juice concentrate) as well as some sugars found in fruit and vegetable juices, jellies, jams, preserves, and fruit spreads”. (Ministry of Health, 2020b)
Free sugar	Free sugars are defined according to the World Health Organization (WHO) definition: “free sugars include monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices, and fruit juice concentrates”. (Ministry of Health, 2020b).

Children are born with an innate preference for sweet and salty tasting foods and a dislike towards sour and bitter foods, making infancy a critical time for promoting the acceptance of healthy foods such as fruits and vegetables (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). The greatest effects on the development of food preferences is likely to occur at the beginning of complementary feeding, and the acceptance of food flavours occurs primarily through frequent and early exposure (Birch & Doub, 2014; Schwartz, Scholtens, Lalanne, Weenen, & Nicklaus, 2011). Excessive total sugar intake during infancy can ingrain and develop an infant's preference for sweet foods.

Given that free and added sugar fails to provide any nutritional benefit outside of contributing to energy intake, intake of these sugars is advised against (Ministry of Health, 2021). Research overseas assessing sugar intake has found that infants are consuming added sugar (Wang, Guglielmo, & Welsh, 2018). Of the foods consumed containing added sugar, commercially available complementary foods (CACFs) tend to have a higher contribution than homemade foods; this is yet to be investigated in NZ. (Foterek et al., 2016). Based on the Australian and New Zealand NRVs, 51g/d of carbohydrates from complementary foods is sufficient for providing infants with adequate energy for growth and development (National Health and Medical Research Council, 2006). It is recommended that infants consume sugars that are naturally present in foods such as fruit, vegetables and milk. Foods containing naturally occurring sugars contribute to carbohydrate content and provide additional nutrients such as vitamins, minerals which contribute to good health (Fidler Mis et al., 2017).

An infant's introduction to complementary foods should be safe, appropriately timed and provide energy and nutrients adequate to support health and growth (Ministry of Health, 2021). The current NZ guidelines for introducing complementary foods from the Ministry of Health (MoH) state that first foods should be a thin, smooth puree and progress in quantity and texture towards family foods by around 1yr of age (Ministry of Health, 2021) . This method of feeding is referred to as traditional spoon feeding (TSP). In recent years an alternate feeding method, baby led weaning (BLW), has become increasingly popular (Rapley & Murkett, 2008). During BLW, the infant has the opportunity of selecting and picking up desired food from what is offered, rather than being fed by a caregiver (Williams Erickson et al., 2018). This feeding approach starts when the infant is ready for solid foods, at around six months of age. These feeding practices widely differ, so it is expected they will influence infant eating behaviour, intake and therefore, health outcomes differently. For example an infant that follows BLW would be expected to have a lower iron intake due to foods not being fortified, and have better regulation of food intake based on satiety cues aka better 'satiety responsiveness' related to speed of eating (Brown & Lee, 2015; D'Auria et al., 2018).

Commercially available complementary foods (CACFs) are commonly consumed by infants within NZ for reasons including convenience, safety and fortification (Ministry of Health, 2021). These CACFs are regulated in NZ by the food standards Australia and New Zealand code and must follow specific guidelines and labelling laws around sugar composition. Particular focus is placed on free sugar, regulating the amount contained within foods marketed toward infants (Food Standards Australia & New Zealand, 2016,). A recent World Health Organisation (WHO) report found over half of CACFs products had sugar contributing more than30% of the energy content (World Health Organization, 2019). Many were sweetened with concentrated fruit juice, contributing to the free sugar content (World Health Organization, 2019). In a recent study, the composition of CACFs within NZ was reviewed, revealing that pouches foods contained similar amounts of free and added sugars; however, they contained three times as much total sugar as non-pouch foods (Katiforis et al., 2021). An additional issue is the large proportion of CACFs containing sweet vegetables such as kumara and carrot, to ensure a sweet taste (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). The way foods are fed to infants may also impact on sugar intake, for example, fed being directly from a pouch or via a spoon, or whether the infant feeds themselves compared with being fed by an adult. When pouches are sucked from directly, infants are at greater risk of developing dental caries and are likely to have higher energy and total sugar intake due to being able to consume a larger quantity more easily (Koletzko et al., 2018).

1.2. Purpose of this study

The current research on total, free, and added sugar intake of infants in NZ is highly limited, with only one study assessing added sugar intake (Williams Erickson et al., 2018). This study found Intake of added sugars was minimal in infants that were 7 months but excessive in infants at 24 months (Williams Erickson et al., 2018). Further investigation is required to better understand the sugar intake of infants across New Zealand (NZ).

The purpose of this study is to investigate total, free, and added sugars of NZ infants, the major contributing food sources and the contribution of commercially available foods to sugar intake, and to explore the potential effects of different feeding methods on sugar intake. Results will give insight into what sugars, and how much sugar, NZ infants are consuming.

1.3. Aim

To investigate the quantity of total, free and added sugars in the diets of infants from the First Food study in NZ and explore the food sources and feeding practices contributing to these sugar intakes during complementary feeding.

1.3.1. Objectives

1. To describe the total, free and added sugar intake of the infants
2. To describe the major food sources of the total, free and added sugars in the infant's diets
3. To determine the contribution of commercial infant foods to total, free and added sugar intake.
4. To describe the differences in total, free and added sugars intake by baby led weaning, pouch use and a traditional approach to complementary feeding

1.3.2. Hypotheses

1. NZ Infants aged 7 to 9.9 months will exceed recommendations for free and added sugar intake according to the MoH guidelines
2. The major food groups contributing to total, free and added sugar intake in infants aged 7 to 9.9 months will come from commercially available infant foods
3. The contribution of commercially available infant foods to total, free and added sugar intake will be greater than that of non-commercial foods in infants aged 7 to 9.9 months
4. Total, free and added sugars will be higher for infants 7 to 9.9 months frequently fed via pouched foods compared with those occasionally or never fed pouched foods .

1.4. Thesis structure

This thesis is divided into four chapters. Chapter one is an introduction to the background, purpose, aims, objectives, and hypotheses of the study. Chapter two is a narrative review of the current literature on infant total, free and added sugar intake, food sources, feeding practices, pouch use and commercial/non-commercial foods. Chapter three is presented as a manuscript for publication and includes the methods, results and discussion. Chapter four outlines how the aims and objectives were met and describes the study conclusions, including strengths, limitations and recommendations. The appendices include supplementary results and copies of the questionnaires.

1.5. Researcher contributions

Table 1.2. Researchers' contributions to this study

Author	Contribution to thesis
Annabelle Malone MSc Nutrition and Dietetic candidate	Primary author of this thesis and responsible for the literature review, data analysis, interpretation of results and finalising and submission of thesis chapters and manuscript. Member of the First Foods research team, with roles in recruitment and data collection
Associate Professor Cath Conlon Academic Supervisor	Academic supervisor, Investigator on the First Foods Study. Contribution to the concept and design of the study, development of the methods and interpretation of the data. Reviewed the thesis.
Professor Pamela von Hurst Academic Supervisor	Academic supervisor, Investigator on the First Foods Study. Contribution to the concept and design of the study, development of the methods and interpretation of the data. Reviewed the thesis.
Associate Professor Kathryn Beck Academic Supervisor	Academic supervisor, Investigator on the First Foods Study. Contribution to the concept and design of the study, development of the methods and interpretation of the data. Reviewed the thesis.
Jill Hazard Statistician	Collated and sorted data and advised on data analysis

Chapter 2: Literature Review

2.1. Introduction

This review explores total, free, and added sugar intake during infancy, including sources of intake and factors affecting intake specific to this population, including feeding practices (pouch feeding, baby led weaning, and traditional spoon-feeding). Relevant literature was identified by searching online databases (Google Scholar, PubMed, and Web of Science). Statistics and recommendations within New Zealand were derived from the Ministry of Health (Ministry of Health, 2020a, 2021). Search terms used were based on study objectives (figure 1)

Date searched: January 2021- August 2021

Search criteria:

Babies OR baby OR infant OR newborn

Intake OR diet OR consumption

Sugar* OR carbohydrate* OR sucrose

Total OR combined OR added OR free

Feeding regime OR Baby led weaning OR pouch use OR traditional spoon feeding

Food sources OR food groups OR commercial foods OR homemade foods

Filters:

Past 5 years, past 10 years, past 15 years

Electronic databases:

Massey Discover, Google Scholar, PubMed and Web of Science, Statistics New Zealand

Figure 2.1. Search strategy for literature review

Keywords and combinations were identified in free text, article titles, and abstracts and were used to thoroughly search the databases. The search focused on articles published before October 2021 and was limited to those published in English. Reference lists from relevant articles were also searched.

2.2. The importance of nutrition during infancy

Optimal nutrition during early life is important in the formation of eating habits and behaviours that support health and growth (Birch & Doub, 2014). An infant will develop food preferences and become accustomed to foods through experience and exposure, in which the brain builds synaptic connections to ingrain proclivity to certain flavours, foods and textures (Murray, 2017; Ventura & Worobey, 2013). Prior to introducing solid foods, an infant is fed breast milk and/or infant formula only. When additional foods are introduced, an infant will experience the largest dietary change in human life, which has both short and long-term effects on health status (Lioret, McNaughton, Spence, Crawford, & Campbell, 2013). The types and timing of food introduced have subsequent effects on infant development and nutritional status (Schwarzenberg & Georgieff, 2018). Ideally in NZ, parents should provide their infant with age-appropriate and nutrient-rich food, as outlined in the Ministry of Health (MoH) guidelines (Ministry of Health, 2021).

There are gaps in the evidence regarding dietary intake in infants, despite the important role of early nutrition on health. Gaps include descriptive analyses of the current total, added and free sugar intake of infants and may be attributed to the challenge of obtaining accurate dietary records, resulting in limited understanding of nutritional intake for this population group. Additional research is required to better understand the dietary intake of NZ infants. Dietary intake in NZ has been assessed previously in the growing up in NZ study, however, of relevance to this thesis - sugar intake, has not (Morton et al., 2012).

2.3. Breast milk and breast feeding

Breast milk is a complete nutrition source until around six months of age, providing an infant with the appropriate amounts of macro and micro-nutrients, digestive enzymes, and immuno-protective substrates (Motee & Jeewon, 2014). WHO recommends exclusive breast feeding for the first six months, followed by breast feeding with the inclusion of complementary foods until around two years of age (World Health Organization, 2001). Breast feeding following this recommendation reduces the risk of childhood infections, including gastrointestinal infection, pneumonia, otitis media and urinary tract infection (Motee & Jeewon, 2014). Long term benefits include reduced risk of obesity, T2DM, and cardiovascular disease (Horta, Loret de Mola, & Victora, 2015; Motee & Jeewon, 2014). A systematic review conducted in 2015 concluded that the odds of T2DM were decreased, and the odds of overweight/obesity were decreased by 13% in people who had been breast fed as infants (Horta et al., 2015). Statistics within NZ show that only half of mothers followed exclusive breast feeding beyond four months, and a mere 7.6% continued until the recommended six months (Ministry of Health, 2020a).

2.4. Complementary feeding

Complementary feeding describes the foods and drinks given in addition to breast milk following exclusive breast feeding (Motee & Jeewon, 2014). Additional foods fill the gap in nutritional needs, where breast milk (or formula) alone are no longer adequate in energy and nutrients (Motee & Jeewon, 2014). Around six months, infants are at increased risk of developing nutritional deficiencies resulting from rapid growth and fast-changing requirements, highlighting the importance of introducing of complementary foods (Ministry of Health, 2021). The first foods recommended for infants are described in the MoH guidelines and include: vegetable and fruit, grain foods, milk products (yoghurt and cheese), legumes, nut butter, eggs, fish, chicken, seafood and chicken or lean red meat. Emphasis is placed on iron rich foods (Ministry of Health, 2021). The foods provided should ideally be whole and less processed. The World Health Organization puts emphasis on nutrient dense foods, specifically animal products (World Health Organization, 2022). The quantity of complementary food offered is not specifically outlined in the MOH infant guidelines, however the world health organization recommends that 6-8 months of age should be offered complementary foods 2-3 times per day. The amount of complementary foods offered then should increase to 3-4 times daily for infants between 9-11 months of age (World Health Organization, 2022). The Queensland

The greatest effects on food preference development is likely to occur when complementary feeding begins, making this period critical for promoting the acceptance of healthy foods such as fruits and vegetables (Birch & Doub, 2014). Food preferences influence eating habits and behaviour's and acceptance of various foods that contribute to a diet supporting growth and health (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). Repeated exposure to particular foods during infancy can result in higher intake of these foods later in childhood (Rose et al., 2017). Infants are born with an innate preference for sweet-tasting foods, which may become further ingrained if they are predominately exposed to sweet complementary foods (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017).

The addition of sugar and other sweeteners to infant food, provides no nutritional benefit and masks the natural flavour of the foods (Ministry of Health, 2021). Introducing a variety of nutritious foods low in sugar during complementary feeding is key, as infants readily accept new flavours, whilst children beyond toddler years do not (Forestell, 2017; Ventura & Worobey, 2013).

2.4.1. Commercially available complementary foods

Around the world there are a range of commercially available complementary foods (CACFs). In developed countries CACFs are readily available and offer parents or caregivers a convenient means of feeding their infants. The extent to which complementary foods are regulated by legislation varies between countries and regions (Padarath, Gerritsen, & Mackay, 2020). Such regulations are built around the manufacturing, fortification and promotion of complementary infants foods. CACFs sold overseas as well as in NZ have been found to defy the national and international guidelines by containing added or free sugars. These guidelines include the MoH and WHO guidelines and country specific guidelines including Australia, Canada, USA and European guidelines detailed in Table 2.1. Almost 30.0% of CACFs in Austria, 32.6% of CACFs in Israel, 37.5% of CACFs in Hungary, and 41.4% in Bulgaria contained added sugars and sweeteners like fruit juices and concentrates. In the USA, more than 70.0% of CACFs for toddlers contained one or more added sugars. In New Zealand 34% of CACFs marketed towards infants and toddlers (4 to 12+) months contain free sugar. (Padarath et al., 2020)

Commercially available complementary foods are associated with greater sugar intakes, which may be associated with the higher added sugar content of such foods, as well as the inclusion of fruit and sweet vegetables (Foterek, Hilbig, & Alexy, 2015). Meanwhile, home prepared foods have been associated with greater diversity in the diet and lower adiposity in infancy (Thompson, 2020). A longitudinal UK study found that by age seven, intake of a variety of fruit and vegetables was increased compared to children who had consumed commercially available foods as infants- likely due to the flavour preference developed during complementary feeding (Coulthard, Harris, & Emmett, 2010). This provides incentive to promote homemade foods that are low in sugar as opposed to commercially available foods for infants. As identified in the MoH guidelines, CACFs are a convenient alternative to homemade foods, however should be used in moderation, as they may reduce variety of flavours and textures in an infants diet (Ministry of Health, 2021). A similar statement is seen in a position paper by ESPGHAN " Infants should be offered foods with a variety of flavours and textures including bitter-tasting green vegetables" (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). Consumption of commercial foods at six months of age tracks to consumption of commercial foods at age 2. Concerns around CACFs have been raised around taste profile as well as total and added sugar content (Maslin & Venter, 2017; Smithers et al., 2012).

2.5. Health consequences associated with high intake of sugars

Excess free and added sugar intake is associated with negative health outcomes. Short-term outcomes include nutrient displacement and positive energy balance. Medium to long term outcomes include diabetes, cardiovascular disease, and poor dental health (Foterek et al., 2016). These medium to long term outcomes tend to occur later in later following the long term excess consumption of free and added sugars. Excess added sugar according to the USDA (United States Department of Agriculture) is consumption over 10% of total energy in those aged two years and older (*Dietary Guidelines for Americans 2020-2025*, 2020). Free sugars are associated with creating a positive energy balance and contributing to undesirable weight gain (Romieu et al., 2017). Excessive intake of free sugars and added sugars may lead to nutrient displacement in diets low in energy, where foods that contribute to good nutrition are consumed in lesser amounts (Frary, Johnson, & Wang, 2004). Low intake of nutrient rich foods can cause nutrient deficiencies which lead to poor health outcomes (DiNicolantonio & Berger, 2016; World Health Organization, 2015a). Although added sugar may provide energy (17kj/g) they may hinder the production of energy. During digestion of added sugar, nutrients from other foods eaten and from body stores may become depleted whilst added sugars are oxidised to energy (DiNicolantonio & Berger, 2016). **Furthermore, mitochondria become damaged during the processing of added sugars, impairing energy generation (DiNicolantonio & Berger, 2016).** Infants are especially vulnerable to nutrient deficiencies due to fast-changing nutrition needs and accelerated growth, especially during the early stages of complementary feeding.

2.5.1. Dental caries

Sugar intake is strongly linked to dental caries, the most prevalent non-communicable disease worldwide. Around 530 million children have dental caries of primary teeth, and 2.3 billion people have dental caries of permanent teeth (World Health Organization, 2020). Dental caries occur when plaque forms on the tooth surface and converts free sugar into acid; over time, this acidic by-product breaks down tooth enamel resulting in decay (World Health Organization, 2020). Consistent evidence supports a relationship between the amount of free sugar consumed and poor dental health, making sugar a key target for health interventions (Meier et al., 2017; World Health Organization, 2017).

When an infant transitions from an exclusive milk diet to a diet of various foods and drinks, they become more prone to risk of tooth decay due to exposure to non-milk extrinsic sugar, notably sucrose (Masson et al., 2010). A national survey in the UK identified that that frequent toothbrushing, which protects against caries and other poor dental health outcomes, does not outweigh the risk of frequent free and added sugar consumption (Masson et al., 2010).

Within New Zealand, the percentage of children aged five years with dental caries was 41% in 2018 (Environmental Health Indicators New Zealand, 2020). Although dental health is affected by other factors such as fluoride in toothpaste and brushing teeth, non-milk extrinsic sugars and sucrose intake are major contributors to tooth decay and thus should be a focal point for intervention around oral health (Environmental Health Indicators New Zealand, 2020). Outcomes of poor dental health include dental pain, difficulty chewing, weight loss and disturbed sleep, leading to poor quality of life (Ladewig et al., 2018; Wagner & Heinrich-Weltzien, 2017). Early childhood caries (ECC) is associated with malnourishment, underweight and iron deficiency anaemia, and increased risk of caries in permanent teeth (Wagner & Heinrich-Weltzien, 2017). One cohort study found that the risk of dental caries in permanent teeth was increased threefold in children who had experienced dental caries in primary teeth, compared to children who had not previously had dental caries (Li & Wang, 2002).

2.5.2. Long-term health consequences of excess added sugar intake

Eating behaviours and habits developed in infancy can track through to childhood and adulthood thereafter (Foterek et al., 2016). High added sugar intake contributes to a diet low in nutritional value and high energy density, leading to an increased risk of developing preventable non-communicable diseases such as CVD and T2DM (Foterek et al., 2015; Stanhope, 2016). Many epidemiological studies show that the greater the intake of added sugar, the higher the risk - regardless of body weight or total energy intake in adulthood (Stanhope, 2016). Added sugar intakes derived from the National Health and Nutrition Examination Survey (NHANES 2009 to 2012) found US children consume far beyond recommended daily intakes for added sugar of 25g/d in children and 0g/d in children under two years (Vos et al., 2017). Intake of added sugar is associated with increased risk of cardiovascular disease in children through increased energy intake, increased adiposity and dyslipidaemia. Current consumption of added sugar in US children is far higher than the intake of added sugar associated with these cardiovascular disease risk factors (Vos et al., 2017).

2.6. Key differences between free and added sugar

Free sugar and added sugar are both terms used within the literature. Although the terms are similar, they have defining differences, which mean they should not be used interchangeably. Unlike added sugar, free sugar includes all naturally occurring sugars in nonintact (i.e., juiced or pureed) fruit and vegetables (Mela & Woolner, 2018). All added sugar can be labelled free sugar, and both exclude all naturally occurring sugar in dairy foods and in intact (fresh, cooked, pureed, or dried) fruit and vegetables.

While added sugar tends to describe the same group of sugars as free sugar, the term free sugar is more defined. This becomes apparent when looking at the likes of concentrated fruit juice, which no doubt contains free sugar but may or may not contain added sugar (Mann, 2014). This may be unclear as the manufacturing process is unknown, i.e. sugar added during processing versus naturally occurring sugar. The use of the term free sugar is now becoming more widely used within research (Mann, 2014).

2.6.1. Difficulties with defining added sugar

Ingredient lists found on commercial foods are not sufficient to define naturally occurring sugars versus those added during manufacturing, creating confusion when it comes to analysing added sugar content of such foods (Mann, 2014). The definition for added sugar varies depending on how the researcher chooses to define added sugars and/or the methodology in which the level of added sugars is estimated within the foods (Mann, 2014).

The Specialist Advisory Committee on Nutrition to the United Kingdom government published a draft report recommending the term free sugars for use in guidelines, and since, the term free sugars has become more widely used (Mann, 2014). Other terms form grey areas when describing sugars, e.g., raw sugar, unrefined sugar, and natural sugar. All of these are free sugars (Mann, 2014).

A New Zealand study reviewed the sugar content of a range of infant foods, assessing both free and added sugar (Katiforis et al., 2021). Following entering the foods within the database, adjustments were made to ensure the analysis fit the definitions used by USDA for added sugars and WHO for free sugars. In total, eleven products required adjustments to accommodate the added sugar definition for juice, concentrates and twenty-four products needed adjustments to fit the free sugar definition for products containing fruit and vegetable sugars (including tomato paste and boysenberry juice). Such adjustments were made to the free and added sugar values produced by food works, following the recipe analysis of these foods. The adjustments made for free sugars were minor (<1g/100g) and none were over 2g/100g. The adjustments made for added sugars were much more significant (up to 20g/100g), primarily due to the higher concentration of nutrients in these foods (Katiforis et al., 2021). Recipes of food products created by manufacturers might also change and therefore change the level of free and added sugar in the food product. This means analysis and data are only accurate for the recipe at the time of analysis if a recipe changes.

2.6.2. Nutrient labelling on commercial foods

Nutrient labelling on foods does not always proclaim the most accurate sugar composition of a product (Walker & Goran, 2015). Walker et al. (2015) used gas chromatography to determine the accurate sugar composition of foods commonly consumed by infants, finding 25% of foods had a total or added sugar content that deviated either <10% or >10% from the label. Baby foods indicating 'no added sugar' had a high sugar content, including fructose and sucrose (Walker & Goran, 2015). More accurate and comprehensive sugar labelling and the inclusion of added sugar on the label should be considered as a health intervention to prevent excess intake of total and added sugars, especially for foods and beverages marketed towards infants. The current American Food and Drug Administration (FDA) and Food Standards Australia New Zealand (FSANZ) do not currently require either added or free sugar to be added to the label and allows for up to a 20% margin of error (Food standards Australia & New Zealand, 2021; Pomeranz, 2012)

2.7. Infant feeding guidelines and recommendations

2.7.1. Infant carbohydrate intake recommendations

For 8 to 12 months old infants the recommended carbohydrate foods include porridge, wheat biscuits, infant cereals, yoghurt, bread, and soft fruits and vegetables (Ministry of Health, 2021). Breast milk and infant formula are important sources of carbohydrates and considered in the recommendations for adequate carbohydrates from complementary foods. In New Zealand the adequate intake (AI) for carbohydrates from complementary foods is 51g/d, for infants aged 7 to 12 months (National Health and Medical Research Council, 2015). As intake of breast milk/formula decreases, a greater quantity of carbohydrates becomes derived from complementary foods. Carbohydrates are macronutrients that consist of sugars and starches which provide energy for growth and brain development.

There is no AI for carbohydrates past infancy as it is unknown whether gluconeogenesis can provide all the glucose requirements of infants (National Health and Medical Research Council, 2015). Gluconeogenesis is a metabolic pathway that results in the generation of glucose from certain non-carbohydrate carbon substrates.

2.7.2. Recommendations for fruit consumption

Naturally occurring sugars, such as fructose from fruit, contribute to total sugar intake and, depending on the processing, may be considered free sugar, e.g. fruit concentrate, and fruit juice concentrate. Some national guidelines and many paediatric statements advise limiting the intake of free sugar in the form of juice.

It is recommended that fruit juice consumption is avoided in infants under one year of age (Ministry of Health, 2021). Offering fruit juice to infants before solid foods runs the risk of having juice replace breast milk or formula milk and potentially result in the infant having a reduced intake of protein, fat, vitamins and minerals (National Health and Medical Research Council, 2013). Fruit juice contains a high proportion of naturally occurring sugars and thus can be a major contributor to dental caries and increased total sugar intake. Consumption of fruit juice in infants has been associated with inappropriate weight gain, i.e., an infant will either fail to achieve optimal weight gain or gain weight above what is considered appropriate (Heyman & Abrams, 2017).

Fruit contains simple sugars, fructose, and glucose; however, unlike puree and fruit juice, whole fruit is high in fibre and has a low energy density comparatively. As infants develop chewing and motor skills, they can move from purees to soft pieces of fruit and finger foods. As whole fruit requires biting and chewing, it is consumed more slowly than fruit juice and purees. This helps to decrease the total energy intake an infant will willingly consume in a single eating session. Fruit is recommended to provide essential micronutrients needed to reduce the risk of cardiovascular disease, cancer and excessive energy intake (Heyman & Abrams, 2017).

2.7.3. International Infant sugar feeding guidelines

Country specific guidelines are displayed in table 2.1. WHO provides the international recommendation for adults and children "maximum intake of sugars of less than 10% of total energy intake for adults and children, and less than 5% for better health, excluding sugars found in whole fruits, milk and vegetables" (World Health Organization, 2015a). Infant feeding recommendations are created for use by the health care practitioners and those that provide advice on nutrition for babies and toddlers. From these recommendations, resources are developed for the general population to give guidance around infant nutrition. Variations are found between guidelines for different countries. The NZ MoH guidelines are advised by a technical advisory group, including academics, researchers, health professionals and experts in infant feeding.

Other national guidelines within table 2.1. are from developed countries or continents, likely to have similar population needs to NZ. All of these guidelines advise against the consumption of added sugar during infancy. National guidelines do not provide recommendations around how much total sugar is appropriate.

Table 2.1. International Infant feeding guidelines around sugar intake

Country	Guidelines
New Zealand (Ministry of Health, 2021)	Infants should consume foods prepared or pre-prepared without added, sugar, honey or other sweeteners Infants should not be given cordial, fruit drink, flavoured milk, soft drinks or alcohol
Australia (National Health and Medical Research Council, 2013)	Do not add sugar or honey to infant food as this increases risk of dental caries Avoid juices and sugar sweetened drinks. Limit intake of all foods with added sugar Solid foods should be of acceptable taste without added sugar, honey or salt. Consumption of nutrient-poor discretionary foods with high levels of saturated fat, added sugars, and/or salt (e.g. cakes, biscuits and potato chips) should be avoided.
Canada (Government of Canada, 2015)	Recommend foods prepared with little or no added salt or sugar Advise limiting fruit juice and sweetened beverages. Encourage offering water to satisfy thirst
USA (centers for disease control and prevention, 2020)	Foods with added sugars: Foods such as candy, cakes, cookies, and ice cream are often high in added sugars. The American Heart Association recommends that children younger than 24 months old are not given any added sugars.
EU (European commission, 2019)	No added sugar to homemade baby food Prefer baby food free of sugar/honey/chocolate Limit for added sugar at kindergarten (20-25 g/day) Minimal added sugar

2.7.4. Consensus statements on infant nutrition

The term "consensus statement" refers to statements that are developed by various professional bodies that are experts within a particular field of research. Paediatric consensus statements are created for health care professionals, to help guide parents and caregivers in caring for their children.

Research from these professional bodies is then used to guide and help develop national recommendations. Consensus statements on infant nutrition are displayed in table 2.2. These provide information around how much sugar is appropriate and the foods sources from which these sugars should be derived i.e. natural form as human milk, milk, unsweetened dairy products, and fresh fruits. Many of these statements are referenced within the NZ MoH guidelines including New Zealand Dental Association, Scientific Advisory Committee on Nutrition (SACN), European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition (ESPGHAN) and Canadian paediatric Society (CPS).

Table 2.2. Consensus statements surrounding sugar intake during infancy

Organisation	Statement
New Zealand Dental Association (New Zealand Dental Association, 2008)	Sweet drinks such as fruit drinks and juice, cordials and soft drinks, are not recommended. Cow's milk should not be given before a child is 12-months old. During that year breast milk or infant formula are baby's milk. If babies are not breast fed, whole milk is recommended for children aged one to two years old. Reduced-fat and low-fat milks can be introduced from two years of age and should not be consumed prior.
UK SACN (Scientific Advisory Committee on Nutrition, 2018)	The average population intake of free sugars should not exceed 5% of total dietary energy for age groups from 2 years upwards and the consumption of sugar-sweetened beverages should be minimised in children and adults. In view of the high intakes of salt (sodium chloride) and free sugars in this age group, there is a need to re-emphasise the risks associated with added salt and free sugars in foods given to infants during the complementary feeding period and to keep reported intakes under review.
European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition (ESPGHAN) (Fidler Mis et al., 2017)	Intake of free sugars should be reduced and minimised with a desirable goal of <5% energy intake in children and adolescents aged ≥2 to 18 years. Intake should probably be even lower in infants and toddlers <2 years. Sugar should preferably be consumed as part of a main meal and in a natural form as human milk, milk, unsweetened dairy products,

	and fresh fruits, rather than as SSBs, fruit juices, smoothies, and/or sweetened milk products. Free sugars in liquid form should be replaced by water or unsweetened milk drinks. National Authorities should adopt policies aimed at reducing the intake of free sugars in infants, children and adolescents.
American Heart Association (AHA) (Fidler Mis et al., 2017)	Recommends that children consume ≤25 g (100 kcal or ~6 teaspoons) of added sugars/day and to avoid added sugars for children <2 years of age.
United States Department of Agriculture (USDA) (USDA, 2019)	When developmentally ready, introduce nutrient rich complementary food to infants across all food groups, limiting sugars, fats and sodium.
Canadian Paediatric Society (CPS) (Critch, Society, Nutrition, & Committee, 2014)	Advise limiting fruit juice and sweetened beverages. Encourage offering water to satisfy thirst.

2.8. Evaluation of Infant food sources

Commercial foods can be analysed using nutrition information provided by the manufacturer; homemade foods undergo analysis using manually entered recipes and national food composition databases. Due to the variation between availability of foods among countries, the food sources contributing to total and added sugar intake will differ, and the databases used will differ. Categorisation of foods varies between studies as well as the methods in which foods are analysed for nutritional value. Sugar content of a food source may be expressed in various ways. Measures include sugar concentration per 100g, percentage of kilojoules from sugar, amount of added or free sugars and sugars per serving size (Cogswell, Gunn, Yuan, Park, & Merritt, 2015). Between studies, sugar content may be compared either through a standardised measure e.g. sugar content per 100g in one study with sugar content per 100g of another, or sugar content per serving size. Dependant of method of data collection, comparisons are not always possible. Different infant foods from around the world have been analysed for sugar content. Findings show an abundance of infant foods contain sugar above the MoH guidelines as displayed in Table 2.3.

Analysis of infants' diets provides data on the total and added/free sugar intake as well as food sources contributing to sugar intake. As many foods tend to be eaten in conjunction with other foods, sugar intake assessed by food groups provides more valuable insight, highlighting what meals are commonly eaten by infants and what meals contribute to excessive sugar intake. Each study chooses to investigate a particular form of sugar. Infant food sources include any foods and liquids fed to an infant, including breast milk, formula and complementary foods. Up-to-date evidence on the composition of commercially available CACFs is available in New Zealand which means the evidence is still valid, providing valuable insight into foods currently available on the market (Katiforis et al., 2021; Padarath et al., 2020). Studies evaluating food sources of the total, free and added sugar intake in developed countries have been selected in this review, as they are likely to give a better representation for comparison of foods sources and sugar intakes of infants in New Zealand.

Of the eight studies included in this review investigating sugar content contained in CACFs, seven used nutritional information supplied by manufacturers to inform sugar content (nutritional panels found on physical products, supplier websites, and online national databases) (Cogswell et al., 2015; García, Raza, Parrett, & Wright, 2013; Katiforis et al., 2021; Koo, Chang, & Chen, 2018; Padarath et al., 2020) . One study used laboratory determined values to review the exact sugar content found within the foods and compared this with the nutritional label supplied by the manufacturer (Walker & Goran, 2015). Sugar in infant foods is broken down into categories based on the food type and listed ingredients. Groups identified vary slightly between studies. These studies are summarised in Table 2.3 which provides information on the study design, methods, sugar content of foods analysed, and study limitations.

2.8.1. Sugar content of CACFs overseas

Among studies, the mean total sugar content was found to be the highest in a cross-sectional survey study completed in the U.K. in 2013. CACFs within this study were broken down from three main food groups- “ready-made spoonable”, “savoury meals with meat/fish/chicken” and “dry finger foods and snacks”. Sub groups were used to identify more specifically which foods contained higher amount of total sugar. For example the subgroup, “sweet contains fruit” under ready-made spoonable contained 10.3g/100g dry finger foods and snacks contained 31.8g/100g. Sub groups with fruit included were found to have a higher total sugar content than other sub groups such as “sweet non fruit” and “savoury” (García et al., 2013).

Cogswell et al. (2015) and Walker et al. (2015) investigated sugar content of CACFs in the USA using a cross-sectional study design. Cogswell et al. (2015) found 44% of CACFs contained >35% total energy from sugar and Walker et al. (2015) found 35% of infant foods contained >50% energy from sugar.

Both studies also investigated added sugar content, finding that most CACFs contained added sugar. Cogswell et al. found that of the ready to serve mixed grains and fruits, 52% contained more than or equal to 1% added sugar. Walker et al. (2015) investigated sugar contents of different infant foods using the method of gas chromatography, a highly accurate method of determining food composition. It was found that of the 100 samples, 74% contained ≥ 20% of total energy per serving from added sugar. Both studies took place in the USA in 2015, however grouped foods differently making comparisons difficult. Cogswell et al. (2015) reviewed a much broader range of infant foods (1074 foods), whilst Walker et al. (2015) reviewed 100 samples only.

Koo et al. (2018) found the highest total sugar composition of infant foods was from infant cookies at 22.1g/100g, followed by simple purees at 6.1g/100g, which included commercial and non-commercial foods (Koo et al., 2018). The sample size in which Koo et al (2018) had was 363, which is much smaller than that of other studies. It is also important to note that the foods commonly eaten and sold to infants in Taiwan include infant cookies which are not available in NZ. Infant cookies contained the highest sugar content by 16g of total sugar. Koo et al. also investigated total sugar content and found that 54.4% of CACFs contained >10% of energy from total sugar.

2.8.2. Sugar content of CACFs within NZ

The total and free sugars in New Zealand CACFs from the 4 major supermarket chains were analysed using data from the online database Nutritrack, maintained by the National Institute of Health Innovation at the University of Auckland (Padarath et al., 2020). Study results showed 67 with a sweet flavour. Free sugar was present in 100% of desserts, 55.2% of sweet snacks, 36.4% of ready-to-eat breakfast meals, and 33.3% of fruit-based meals (Padarath et al., 2020).

Katiforis et al. (2021) explored the total, free and added sugar content of infant food sold in NZ per 100g using nutrient data from FoodWorks, FOODfiles 2018. Foods (n= 266) were examined across 19 brands (Katiforis et al., 2021). Of the 58 snack foods identified, 33 (56.9%) contained at least one source of free sugars and 30 (51.7%) contained at least one source of added sugars. Given infants are recommended to consume no added sugar according to the MoH guidelines, this is of concern. On average, 16.0% of the energy content of "sweet snacks" was from free sugar, whereas free sugar did not provide any of the energy content of "savoury snacks" (median 0.0%). Total sugar was found to be highest in sweet snacks, with a median value of 22.3 g/100 g vs 4.3 g/100 g for savoury snacks (Katiforis et al., 2021). Foods were split into pouched and non-pouched categories. Pouched foods were defined as pouches with nozzles, from which the baby can directly suck, and non-pouched foods were all other foods. Pouched foods were lower in free sugar, with 79.2% containing less than 1g of free sugar per 100g. On average, neither "pouches" nor "non-pouches" contained free or added sugars. The foods that contained more than 5g/100g of free or added sugars were custards. Total sugar across all infant age groups had a median value of 8.4g/100g for "pouches" and 2.3g/100g for "non-pouches" (Katiforis et al., 2021).

Both NZ studies used different methods to analyse the total, free and added sugars making it difficult to compare results. The years in which these studies took place are relatively current (2020 and 2021) and likely to represent the current market of infant foods sold within NZ (Katiforis et al., 2021; Padarath et al., 2020). Given the small evidence base, more evidence using the same analysis methodology would be beneficial in understanding the total, free and added sugar content of infant foods sold within NZ.

2.8.3. Sugar content of CACFs- summary

All studies were an observational study design reviewing food sources that were current at the time in which the study took place. Overall, free sugar and added sugar were found in infant foods, and most infant foods contained ingredients sweet in flavour (regardless of sample size), which may hinder the ability of infants to develop a wider flavour preference (Cogswell et al., 2015; García et al., 2013; Katiforis et al., 2021; Padarath et al., 2020; Walker & Goran, 2015). The national guidelines of countries in which these studies took place (NZ, US and UK) advise against the use of added and free sugars in infant foods; however, they appear to allow foods containing these sugars to be sold and marketed towards infants.

Although studies measure sugar and types of sugars using different methods, all point to the same conclusion- added and free sugar composition in CACFs does not align with national recommendations. Current food labelling legislation does not require free and added sugar content to be stated on the nutritional panel for CACFs.

Table 2.3. Studies analysing sugar content contained in commercially available infant food sources

Reference, country	Study design and purpose	Methods	Results	Limitations
(Padarath et al., 2020) NZ	Cross-sectional survey investigating the nutritional appropriateness of CACFS	Information extracted from an online database of CACFs in major supermarket chains	Free sugar contained in CACFs marketed towards infants (4 month, 6 months and 8 months +): • 7 ready-to-eat and 2 dry cereal (breakfast) • 21 custard and pudding (desserts) • 11 fruit meals, 2 fruit and vegetable meals, 1 meat meal • 1 rusk, 3 sweet (snacks) • N=67, 34% of 197 CACFs contained free sugars	• Limited to CACFs in major supermarkets only • Nutritional panel of the foods was used to extract macronutrient content rather than chemical analysis
(Katiforis et al., 2021) NZ	Cross-sectional survey designed to compare the nutritional quality of pouched foods compared to other forms of commercial infant foods	Photographs of CACF packaging and supermarket websites were used to analyse the nutritional composition Nutritional composition of foods identified as CACFs (excluding infant formula) were analysed using the nutrition programme FoodWorks	266 foods identified- including 58 snack foods and 133 food pouches • 33 out of 58 (56. 9%) snack foods contained free sugar • 16% of energy content of sweet snacks was from free sugars • 30 out of 58 (51.7%) snack foods contained added sugar • Total sugar was the highest in sweet snacks 22.3g/100g compared to 4.3g/100g in savoury snacks • Median total sugar content for pouches was 8.4g/100g vs 2.3g/100g for non-pouches	• Specific proportions of ingredients were not reported on all food labels, so they had to be estimated • Some ingredients were not available in FoodWorks so had to be substituted with nutritionally similar foods

(Cogswell et al., 2015) U. S	Cross-sectional survey to evaluate sodium and sugar content of US commercial infant and toddler foods	Using a US commercial nutrition database, infant and toddler foods were identified by entering search terms "baby" and "toddler." Formula, fortified milk and oral electrolytes were excluded	1074 food identified as infant and toddler food and analysed for sugar content: • Of the ready to serve mixed grains and fruits (n=79), 41 foods (52%) contained more than or equal to 1% added sugars, and 35 (44%) also contained >35% energy from sugar.	• Sugar and energy content are based on the label, not laboratory analysis. • The Nutrition Facts label does not include the amount of added sugars, separate from total sugar • Database lacks sales or market share data for individual food products- possible missed products
(Walker & Goran, 2015) U. S	Cross-sectional survey designed to determine the actual sugar content and composition of infant formula and other food products children may be exposed to in early life	Determined actual sugar content by conducting a blinded laboratory analysis in infant formulas, breakfast cereals, packaged baked goods and yoghurts. One hundred samples were sent to an independent laboratory for analysis via gas chromatography Sugar content and composition was determined, and total sugar was compared against nutrition labels.	Of the 100 samples analysed, 74% contained ≥20% of total energy per serving from added sugars. Nutrient label data underestimated or overestimated actual sugars, and 25% of all samples had actual total sugar values that were either <10% or >10% of labelled total sugar. Mean percentage of total energy per serving from sugar in different food groups. • 13.9% contained >50% of their total energy from sugar (yoghurt) • 13.7% contained >20% of their total energy from sugar (breakfast cereal)	• Only 100 foods were analysed, including 60 common grocery items- not all of these items were specifically marketed towards infants.

			• 7.6% of products contained >20% of their total energy from sugars (pre-packaged baked goods)	
(Koo et al., 2018) Taiwan	Cross-sectional survey to compare the food claims of commercial complementary food products with their actual nutrition facts.	A sample of 363 CACFs was collected from websites, local supermarkets, and other food stores, and their nutrition-related claims were classified into composition, nutrition, and health categories. All of the samples were semisolid or solid infant foods. Drinks, soup stock, and milk products were excluded	Total sugar (g) was analysed for 237 infant foods- mean and standard deviation of nutrient content per 100g was calculated per food group • 4.8 ± 3.3g for infant cereal • 6.1 ± 5.0g for simple puree food (single ingredient) • 2.4 ± 3.1g for mixed food • 22.1 ± 20.0g for infant cookies • High sugar content (>10% of the energy from the product as sugar) was found in 54.4% of the CFs	• The sample couldn't cover all available CACFs in Taiwan • Some products lacked sugar content information • Did not use laboratory analysis to verify the nutritional content
(García et al., 2013) U. K	Cross-sectional survey aimed to describe the types of commercial infant foods available in the UK and provide an overview of their taste, texture and nutritional content in terms of energy, protein, carbohydrates, fat, sugar, iron, sodium and calcium.	All infant foods produced by four main UK manufacturers and two more specialist suppliers were identified. Nutritional information for each product was collected from manufacturers' websites, in-store products, and direct email enquiry.	Mean content of total sugar in different food types per 100g ± SD Ready-made (soft, wet) spoonable foods 5.6 ± 4.5g • Sweet fruit only 11.6 ± 2.3g • Sweet contains fruit 10.3 ± 2.3g • Sweet non-fruit 7.8 ± 3.1g Savoury meals with meat/fish/ chicken 2.0 ± 0.9g • Other savoury meals 2.7 ± 1.5g Dry finger foods and snacks 19.46 ± 16.7g • Sweet contains fruit 31.8 ± 20.6g • Sweet non-fruit 20.4 ± 6.6g • Savoury 4.0± 3.7g	• Classification of food types relied on the name of the products. • Data relies on manufacturers' reported nutritional information, so it may not reflect actual nutritional content

2.8.4. Actual sugar intake in infants

Studies assessing actual sugar intake in infants are important for understanding where sugar is coming from in an infant's diet. Foods are assessed by food groups rather than individual ingredients. Food groups showing high levels of sugar consumption can be identified and provide data to formulate targeted interventions thereafter. The place, time, methodology and study results of infant sugar intake are summarised in Table 2.4. The studies within the table are explored in further detail below.

In the USA and Europe sugar intake in infants has been assessed from large longitudinal studies. Grimes et al. (2015) conducted 24hr recalls of infants aged 6-11.9 months (N=854) using data from the NHANES 2005-2012 study to analyse what infants are consuming. CACFS made up 13.3% of total sugar intake and majority of total sugar came from other foods (homemade and non-commercial) (Grimes, Szymlek-Gay, Campbell, & Nicklas, 2015). The mean consumption of total sugar was 77.4 $\pm$ 1.1 g/day total sugar. Of the foods contributing to total sugar, baby foods contributed 13.3% of daily intake, followed by fruit at 4.5% and 100% juice at 3.6% (Grimes et al., 2015).

Forterek et al. (2015) investigated total carbohydrate intake and added sugar in infants 5 to 9 months within Germany using cross-sectional data from the Dortmund Nutritional and Anthropometric Longitudinally Designed Study (DONALD). The median added sugar intake was 4g/d or 2.3% of total energy intake. Commercial complementary foods contributed more added sugar than homemade foods (0.6g/d vs 0.1g/d) (Foterek et al., 2015). Analysis of earlier NHANES data (2009-2014) by Wang et al. (2018) reported that 1.9% of non-breastfed infants aged $\leq$ 1 year (N=776) consumed added sugars above the WHO recommendation of <10% total energy from added sugars. Of the infants, 8.0% consumed free sugar over the recommended amount (Wang et al., 2018). In a study by Sharma et al. (2013) a much smaller sample size of infants (n=20) were investigated within the USA and found the mean daily intake of total sugar for infants 7 to 12 months was 81.5g/d (Sharma et al., 2013).

One study in NZ reported added sugar consumption (Williams Erickson et al., 2018). The study aimed to see if any differences in nutrient intake occurred between a control group of infants fed as usual and an intervention group of infants fed using a modified version of BLW. Infants at 7 months were consuming a mean value of 0.9d/day at 0.6% of total energy intake (control group n=77) to 1.2g/day at 0.7% of total energy intake (intervention group N=85). Infants aged 12 months old were also assessed, with findings showing increased added sugar consumption among the control and intervention groups. The control group (N=76) consumed 6.9g/day of added sugar, equating to 3.5%

of daily energy intake. The intervention group (N=74) consumed 5.8g/day of added sugar, equating to 2.8% of daily energy intake. Both the intervention and control groups consumed added sugar daily, and consumption increased with age. Further investigation needs to be completed with a larger sample size to understand the total, free and added sugar intake that infants consume within New Zealand.

2.8.5. Tracking of an infants' diets across time

A study conducted in Australia showed an increase in energy density of 36% in infants from 9 to 18 months as a result of increased intake of sugar sweetened beverages, meat products and savoury and sweet snack foods (Lioret et al., 2013). Another study in European children showed that a diet high in added sugar, unhealthy fats and low consumption of fish and olive oil was tracked predominantly from 12 to 24 months of age (Luque et al., 2018). Infants with a poorer diet at 9 months, categorised by higher energy density and lower nutrient density continued to pursue the same diet at age 6. Foods commonly consumed included soda and sweet desserts (Rose et al., 2017).

Table 2.4. Studies analysing infant total, free and added sugar intake

Reference and country	Sample size and age	Study design and methods	Results
(Williams Erickson et al., 2018) NZ	162 (7 months) 144 (12mth)	Randomised control trial 3 day weighed dietary records	Added sugar • Mean 0.9-1.2g/day (7 months) • Mean 6.9-5.8 g/day(12 months)
(Sharma et al., 2013) USA	20 (7-12 months)	Cross-sectional dietary survey 2x 24hr dietary recalls	Total sugar (milk feeds included) • Mean 81.5g/day (SD 26.7) Total sugar (complementary foods only) • 38.5g/d (81.5 – 52.8%) 52.8% of total sugars were derived from formula milk feeds and breast milk was not included
(Grimes et al., 2015) USA	854 (6-11.9 months)	Cross-sectional dietary survey 2x 24hr dietary recalls	Total sugar (milk feeds included) • 74.4 ±1.1g/day Total sugar (complementary foods only) • 57g (74.4 – 26%) 26% of total sugars were derived from milk feeds Ranked food sources contributing to total sugars among US infants- the percentage of daily intake (%) 1. Infant formula (53.1) 2. Baby foods (13.3) 3. Human milk (10.6) 4. Fruits (4.5) 5. 100% juice (3.6) 6. Baby beverages (3.6)

			7. Milk (3.1) 8. Yoghurt (1.6) 9. Sweet bakery products (1.3) 10. Sugar-sweetened beverages (1.0)
(Wang et al., 2018) USA	776 (0 to 1 year)	Cross-sectional survey 2x 24hr dietary recall	Added sugar • The proportion of non-breast-fed infants whose consumption exceeded recommended limit of <10% total energy from added sugars was 1.9% (0.7) • Percentage of energy contributed by added sugars from all foods and beverages and beverages only among non-breast fed US infants 1.1 ± 0.1 Free sugar • The proportion of non-breast-fed infants whose consumption exceeded recommended limit of <10% total energy from free sugars 8.0% was (1.2)
(Foterek et al., 2016) Germany	288 (5 to 9 months)	Longitudinal open-cohort study 3- day weighed diet records	Added sugar • Median 4g/d or 2.3% of total energy intake. • Commercial complementary foods 0.6g/d • Homemade foods 0.1g/d

2.9. Infant feeding practices

2.9.1. Types of feeding and recommendations

An infant's introduction to complementary foods should be safe, appropriately timed and provide energy and nutrients adequate to support health and growth (Ministry of Health, 2021). The current NZ guidelines for introducing complementary foods from the MoH state that first foods should be a thin, smooth puree and progress in quantity and texture towards family foods by around one year of age (Ministry of Health, 2021). By nine months of age, the amount of complementary food consumed by an infant should be 2-3 meals per day and 1-2 snacks, dependant on appetite (Ministry of Health, 2021). Over the last 10-15 years, there has been a growing interest and popularity in baby led weaning (BLW), in which the infant controls the weaning process and self-feeds from the start of complementary feeding (Rapley & Murkett, 2008). The MoH does not currently recommend this feeding practice, as safety and health outcomes have not been explored sufficiently (Ministry of Health, 2021).

During BLW, the infant has the opportunity of selecting and picking up desired food from what is offered, rather than being fed by a caregiver. The feeding approach starts when the infant is ready for solid foods. This occurs at around 6 months of age when they can sit up on their own, pick up foods and bring them to their mouth and show signs of being interested in food (Williams Erickson et al., 2018). Although parents offer foods, the infant chooses what, how much and how quickly to eat. BLW is an alternative approach to the traditional spoon-feeding (TSP) practice in which an infant is fed progressively towards solid foods (Ministry of Health, 2021). TSP begins with smooth purees, then mashed and chopped foods, then finger foods and small bites. The gradual changes allow the infant to slowly adapt and learn to eat foods at different levels of texture and size (Morison et al., 2016). As the feeding practices widely differ, it is expected that each practice may influence infant eating behaviour, intake and therefore, health outcomes differently. These differences may include variation in energy intake, macro and micronutrient intake, developmental progress (progression towards family meals).

2.9.2. Baby led weaning and traditional spoon feeding and associations with sugar intake

BLW is not recommended as a sole approach from six months by agencies, including the United Kingdom Department of Health and Health Canada. Instead, these agencies suggest finger food be offered as *part* of the infant's diet from six months (at the beginning of complementary feeding) (Daniels et al., 2015). Little is known about the impact BLW may have on infant total, free and added sugar intakes and the health outcomes of New Zealand infants (Taylor R, 2021). Despite not being recommended by the NZ MoH, many parents/caregivers in NZ are following the BLW approach (Williams Erickson et al., 2018). Although many studies investigating BLW have identified various risks and benefits, concluding opinions differ (Cameron, Heath, & Taylor, 2012; Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). Although there is a growing body of research, evidence to support or discourage BLW is lacking. In a trial conducted by Williams Erickson et al. (2018), added sugar intake was assessed for infants following BLW. Both the intervention and control group followed BLW and had access to routine government-funded midwifery (pregnancy to 4 to 6 weeks postnatal) and well-child (4 to 6 weeks to 5 years of age) care. The intervention group received additional resources and advice over 8 contacts by trained researchers and health professionals. The study followed infants from seven months to two years to assess food and nutrient intake of infants over this time. At seven months 57% of infants from both groups consumed at least one sweet snack during the 3 days of diet record, and 7% had less than 5% of energy coming from added sugars. At twelve months the intake of added sugars diversified between groups; however, added sugar intake was still above the recommendation of <5% energy from added sugars (24-31%). The percentage intake of infants consuming inappropriate amounts of added sugar increased to 70-75% by twenty-four months (Williams Erickson et al., 2018).

A systematic review conducted in 2018 inferred that baby led weaning infants may become more accustomed to sweet and salty foods than traditionally fed infants if the family foods fed to the infant are not appropriate, i.e., contain sugar and salt (D'Auria et al., 2018). In a cross-sectional study by Morison et al. (2016) comparing traditional feeding to baby led weaning, differences in nutrient intake were observed. Diet record data was used to compare the foods offered, including added sugars (>4g/100g of added sugar or honey). It was found that 42% of foods offered to TSF infants included added sugars, and 39% of foods offered to BLW infants included added sugars. There was no significant difference between the groups. Total sugars were then analysed by calculating a mean average intake of the seven days of a weighted dietary record. The mean total sugar intake for TSF infants was 46g and 62g for BLW infants, again with no significant difference between groups (Morison et al., 2016). Current research shows gaps in the evidence around which feeding method is most appropriate for infants. These gaps include how feeding method affects sugar intake and how they may influence sugar intake later in life.

2.9.3. Pouch use and sugar intake

Until recent years, commercial infant foods have come in glass or canned packaging; now, over 70% come in pouches (Katiforis et al., 2021). Pouches allow for on-the-go meals and are quick and easy to use. Given the convenience and ease of feeding infants via infant pouches, this practice has become highly popularised (ABC Packaging Direct, 2017). From 2019-2020 133 out of 266 (50%) CACFs sold within the four major supermarket chains in NZ were pouches (Katiforis et al., 2021). Within the United States, pouches made up 56% of the market share (Beauregard, Bates, Cogswell, Nelson, & Hamner, 2019), and an annual sale growth of 125% in Europe (Nielsen company, 2015). Food found within pouches tends to have a similar composition to other CACFs; however, concern has been raised that added sugar content might be greater (Beauregard et al., 2019; Koletzko et al., 2019; Koletzko et al., 2018; Moding et al., 2019).

The Nutrition Commission of the German Society for Paediatrics and Adolescent Medicine recommends that infants should not suck directly from pouched foods and be offered liquid and pureed foods via a spoon (Koletzko et al., 2019). Koletzko et al. (2018) investigated the implications and potential health downfalls of pouch feeding, including increased sugar intake and developmental delay. Conclusions were drawn based on the form of the food (puree), the ease of consumption, and the high total sugar content of the pouches (up to 90% of energy content). Pureed foods increase blood glucose and insulin levels more so than whole fruit, as digestion occurs faster. A potential consequence of this is undesirable infant weight gain (Koletzko et al., 2018). Pouch food also tends to have a higher energy density. The ease of consuming pouched foods compared to foods that need to be chewed and swallowed leads to a high intake of energy and fructose over a short time. Regular feeding via pouched, pureed foods is not encouraged due to adverse health outcomes such as metabolic issues and undesirable weight gain (Koletzko et al., 2018). This editorial reviewed 10 pouches sold in Denmark in 2017 and did not assess actual intake and subsequent health outcomes; therefore, it cannot conclude the actual effects of feeding infants pouched foods.

Although many pouch foods contain vegetables, they tend to be sweet and cause infants to develop a preference for sweet foods. It has also been documented that weaning an infant off pouches to solid foods is challenging due to the lack of oral development and lower acceptance of novel textures (Koletzko et al., 2019; Padarath et al., 2020). Regular consumption of pouched foods poses the risk of imbalanced nutrient intake, dental caries and undesirable weight gain (Koletzko et al., 2019)

2.9.4. Concluding statement

Current research on total, free and added sugar intake during infancy is limited, but nevertheless, suggests that WHO guidelines are not adhered to. The sugar composition of CACFs have been shown to defy such guidelines, with many containing inappropriate amounts of both free and added sugars. Given the lack of research assessing total, free and added sugar intake, evidence-based information about what NZ infants consume requires review. The ever-changing market of available infant foods and the recent shift in feeding methods provides additional incentive to explore infant intake. Further research will allow for a better understanding of what, how, and how much sugar intake during infancy is apparent today, which will then help guide future interventions and possibly recommendations around sugar intake.

Chapter 3: Research Manuscript: **Sugar intake in babies: an observational study describing total, free, and added sugar intake among seven to ten-month-old infants in New Zealand**

3.1. Abstract

Background: Excess total, free and added sugar intake during infancy can increase the risk of dental caries, nutrient displacement, undesirable weight gain and the development of unhealthy eating habits. Infant feeding recommendations advise against added sugars, honey or sweeteners during the complementary feeding stage as they provide no nutritional benefit. Food sources, feeding practices (baby led weaning and traditional spoon feeding), frequency of pouch use and non-commercial/commercial infant food, require further investigation to better understand sugar intake in New Zealand infants.

Aim: To investigate the quantity of total, free and added sugars in the diets of infants from the First Foods study in New Zealand and explore the food sources, feeding practices and frequency of pouch use contributing to sugar intake during complementary feeding.

Methods: An observational cross-sectional study design was used. Two 24hr diet recalls were conducted with caregivers of 211 infants (aged between 7 to 10 months) across Auckland and Dunedin. Descriptive analyses were carried out to determine, energy and macronutrient intakes, total/free/added sugar intake by food group, feeding practice, frequency of pouch use and commercial versus non-commercial foods. Inferential analyses were run for feeding practice and pouch use to determine whether there was a difference in sugar intake between the groups.

Results: Infants median total, free and added sugar intake from complementary foods was 15.8g/day. 0.5g/day and 0.2g/day, respectively. Total sugar contributed to 18.4% of the total energy intake from all nutrient sources. Infants consumed sugars from 32 defined food groups. The groups 'custards' (5.58g) and 'yoghurt with fruit' (2.18g) had the highest intake of free and added sugar. Free sugar intake was significantly higher in infants following traditional spoon feeding compared to infants following baby led weaning. Added sugar intake was significantly higher in infants following traditional spoon feeding and partial baby led weaning compared to infants following baby led weaning. Frequently pouch fed infants consumed the highest values of total, free and added sugar (19.89g/d, 1.59g/d and 1.19g/d) and Intakes of total, free and added sugar were significantly different between differing pouch use groups (P values= 0.001, 0.0 and 0.018). Non-commercial foods contributed 6.33g/d more total sugar than commercial food; free and added sugar intakes were ≤0.25g for commercial, mixed, and non-commercial foods.

Conclusion: The quantity of total, free and added sugars in the diets of infants diet from the First Foods study was minimal regardless of feeding method, pouch use and commercial and non-commercial foods. The majority of the foods eaten by the infants did not contain free sugar. There were no significant relationships between infants fed via baby-led weaning, partial baby-led weaning, traditional spoon feeing and sugar intake. Infants who were categorised as frequent pouch users had the highest intake of total, free and added sugar compared to infants in the moderate and non-pouch user groups. Parents should be encouraged to choose foods for their infants that are low in total, free and added sugar and to expose their infants to bitter-tasting foods. Parents should take caution with pouch feeding, particularly the frequency in which they feed their infant pouched foods.

Keywords: infant, complementary feeding, sugar intake, food sources, feeding practices, pouch use

3.2. Introduction

Optimal nutrition during early life is important for forming eating habits and behaviours that support health and growth (Birch & Doub, 2014). Breast milk is a complete nutrition source until around six months of age. WHO recommends exclusive breast feeding for the first six months, followed by breast feeding with the inclusion of complementary foods until around two years of age (World Health Organization, 2001). Complementary feeding describes the foods and drinks given in addition to breast milk following exclusive breast feeding (Motee & Jeewon, 2014). Additional foods fill the gap in nutritional needs, when breast milk alone is no longer adequate in energy and nutrients (Motee & Jeewon, 2014). The types and timing of food introduced have subsequent effects on infant neurodevelopment and nutritional status (Schwarzenberg & Georgieff, 2018). Malnutrition during the first 1000 days of life days can result in compromised neurodevelopment, or deficits in brain function, which is associated with more behavioural dysregulation and decreased IQ scores. During this time-frame the brain is developing rapidly; if an infant does not receive adequate nutrients at the required time the brain may not be able to retrieve lost function later (Schwarzenberg & Georgieff, 2018).
The greatest effects on the development of food preferences occur when complementary feeding begins, making this period critical for promoting the acceptance of healthy foods such as fruits and vegetables (Birch & Doub, 2014). Repeated exposure to a particular food during infancy has been linked to a higher intake of these foods later in childhood (Rose et al., 2017). Infants are born with an innate preference for sweet-tasting foods, which may become further ingrained if they are primarily exposed to sweet complementary foods (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). Introducing a variety of nutritious foods low in sugar during complementary feeding is

critical, as infants readily accept new flavours, whilst children beyond toddler years do not (Forestell, 2017; Ventura & Worobey, 2013).

In New Zealand, the MoH recommends infants consume various foods, including fruit, vegetables, breads, and cereals (Ministry of Health, 2021). These guidelines advise that infants consume foods prepared or pre-prepared without "added fat, salt, sugar, honey or other sweeteners" and are not given "cordial, fruit drink, flavoured milk, soft drinks, tea, coffee or alcohol" (Ministry of Health, 2021). Sugar does not provide any nutritional benefit aside from energy and may result in an ingrained preference for sweet-tasting foods (Ministry of Health, 2021; Padarath et al., 2020).

As pouch feeding and BLW are both new ways of feeding infants, little is known about the impact they have on total, free and added sugar intakes of New Zealand infants (Taylor R, 2021). Pouches are defined as plastic squeezable containers with a nozzle attachment that an infant can suck from directly. BLW is where the infant feeds themselves with finger foods rather than being feed by an adult progressively from purees to solid food. Although many studies investigating BLW have identified various risks and benefits, concluding opinions around are in dissent. Risks include iron deficiency, inadequate energy intake and choking. Benefits include more shared family meals, promotion of healthier eating behaviours and greater convenience for mothers. (Cameron et al., 2012; Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). A systematic review conducted in 2018 inferred that baby led weaning infants may become more accustomed to sweet and salty foods than traditionally fed infants if the family foods fed to the infant are not appropriate, i.e., contain sugar and salt (D'Auria et al., 2018). BLW is not recommended as a sole feeding approach from six months by the MoH, United Kingdom Department of Health and Health Canada. Instead, current recommendations promote finger food to be offered as *part* of the infant's diet from six months (at the beginning of complementary feeding) (Daniels et al., 2015; Ministry of Health, 2021).

Although many commercially available pouch foods contain vegetables, they tend to be sweet due to the addition of fruit or sweet tasting vegetables (carrot, kumara, pumpkin etc.) and therefore cause the infant to develop a preference for sweet foods. Weaning an infant off pouches to solid foods is more challenging than that of other feeding methods due to the lack of oral development and lower acceptance of novel textures (Koletzko et al., 2019; Padarath et al., 2020). Furthermore, regular consumption of pouched foods poses the risk of imbalanced nutrient intake, dental caries and undesirable weight gain (Koletzko et al., 2019)

An increasing number of infants are consuming energy-dense foods and foods high in added sugar (Birch & Doub, 2014; Butte et al., 2010; Thompson, 2020). High added, and free sugar intake during infancy is associated with increased risk of dental caries, the most prevalent non-communicable disease worldwide (Masson et al., 2010; World Health Organization, 2017). High total sugar intake can lead to nutrient displacement, undesirable weight gain and the development of unhealthy eating habits (Foterek et al., 2016; Romieu et al., 2017). The value of sugar intake considered high Is determined differently by different studies and varies by participant age. For example, Foterek et al 2016, defined high total sugar and high added sugar as values exceeding the 75th percentile. High added sugar from complementary foods was defined as intakes above 2.6% of total energy per day or 4.4 grams per day respectively (Foterek et al., 2016).

Two recent studies have assessed the sugar content of commercially available complementary infant food (CACFs) sold within NZ. Padarath (2020) found 34% of CACFs contained free sugars, while Katiforis (2021) found both free and added sugar in a large proportion of CACFs (predominantly in snack foods and custards). Both studies found that majority of the CACFs were sweet in flavour, either through the addition of fruit or sweet vegetables (e.g., kumara, carrot and corn).

There is limited evidence on total, free and added sugar intake of New Zealand infants. As sugar intake during infancy may lead to poor eating behaviours and subsequent health outcomes, it is crucial to further explore sugar intake occurs in New Zealand infants. This research describes the quantity of total, free and added sugars in the diets of infants within New Zealand and explores the food sources, feeding practices and frequency of pouch use contributing to sugar intake during complementary feeding.

3.3. Methods

3.3.1. First Foods study

The 'Dietary sugar intake from complementary foods' study was undertaken as a part of the First Foods New Zealand study, exploring intake of total, free and added sugar intake of infants. The First Foods study is an observational cross-sectional design that aims to recruit 625 infants across Dunedin and Auckland. The purpose of the First Foods study is to investigate what infants are eating when they move from an exclusive milk diet to complementary foods and how this may relate to infant growth and development. The protocol for the First Foods study has been published (Taylor R, 2021).

The First Foods study included two times twenty-four hour diet recalls and an online questionnaire (describing health, demographic, and infant feeding), which was used within this study. These were undertaken from July 2020 to September 2021. Specific comparisons were made between infants using baby food pouches with those not using pouches and those following baby led weaning (BLW) with traditional spoon-feeding (TSF).

3.3.2. Funding and ethics

Ethical approval was granted from the Health and Disability Ethics Committees New Zealand (19/STH/151). The study was funded by the Health and Research Council (HRC) of New Zealand (grant 19/172). Australian New Zealand Clinical Trials Registry: ACTRN12620000459921.

3.3.3. Participants and Recruitment

This study will present data on 211 infants, the number of infants with analysed twenty-four hour recalls and completed study questionaries by August 2021. To be eligible for the study, infants had to be between seven and nine-point-nine months of age at the time of data collection, and the parent/guardian of the infant had to be aged sixteen years or older and able to speak English. Recruitment was done via advertisement, including posts on Facebook pages, word of mouth, and flyers. Targeted recruitment was completed. A count of participants in each ethnic group was completed around three-quarters of the way through recruitment. Ethnic groups under-represented in the data set were targeted, with the goal of collecting data representative of the general population of NZ. Māori and Pacifika communities were sought out by engaging with community health organisations, targeted recruitment within suburbs high in Māori, Pacifika and Asian persons, and having research team members who identify with or have past working experience with Māori, Pasifika, and Asian communities.

3.3.4. Health and demographic data

Parents/guardians completed an online health and demographic questionnaire which collected data on infant age, weight, length, BMI Z score, sex, ethnicity, parity and deprivation index, and parent age and ethnicity. Infant length was measured using a length mat and infant weight was measured using baby scales. Age was stratified by month (seven, eight and nine months of age), and ethnicity was stratified into five ethnic groups using "prioritised ethnic categorisation" (Boven, Exeter, Sporle, & Shackleton, 2020). Individuals were classified into a single ethnic group, in prioritised order as follows: Māori, Pasifika, Asian, Other and New Zealand European (NZE). NZ deprivation categories are based on the "NZDep2013 index of deprivation ordinal scale", which scores areas from 1-10. Deprivation scores were then grouped into three categories as follows: 1-3= low deprivation, 4-7= medium deprivation, 8-10= high deprivation (Atkinson, Salmond, & Crampton, 2014).

3.3.5. Twenty-four hour dietary recall

To determine the food and drink an infant had consumed the previous day, two twenty-four hour dietary recalls were conducted in chronological order of consumption from 12 am midnight to 12 am midnight the following day by a trained researcher. Before the interview, the parent/guardian was asked to take pictures of all the foods fed to the infant the previous day using a personal mobile phone or camera, or a camera provided by the study. These images were used to aid with analysing what, when and how much the infant consumed. The second recall was conducted approximately one week later than the first recall and held on a different day than the first recall. Having recalls undertaken on different days of the week avoided gathering routine foods consumed on a single given day. The second dietary recall was conducted using the same methods and protocol as the first visit.

A 3-stage approach was followed to ensure all food and drinks were accurately recorded. Stage 1 involved collating a ‘quick list’ where the interviewee was asked to list all the foods and drinks their infant had consumed. Stage 2, the detailed list, involved collecting information on the amount of each food consumed, where and how the baby was fed. Researchers had a food description prompt sheet to aid with details. Props such as measuring cups, wooden blocks, coffee beans, teaspoons/tablespoons and the countdown website were used to help the interviewee to identify specific amounts and brands of products. Stage 3 involved a review of the recall and probing questions to see if there was any missing foods. If the infant was fed by another adult, a separate form was filled out by the adult that fed them. This was filled out without the presence of a trained interviewer, and step by step instructions were given to improve the accuracy of the record.

During the first study visit, following the 24hr recall, the parent/guardian was asked whether any drinks other than breast milk, formula, or water were offered and if any sugar was added to any foods or drinks offered to their baby. This included any sugar and or salt is added to family foods offered to the infant. As these questions were based on the infant’s diet history and not limited to the foods and drinks within the twenty-four hour recall, there was no need to ask again at the second visit. Milk intake from breastfeeds was also documented, however this data has not been used in this study.

3.3.6. Methods of feeding

During the first visit, an online questionnaire was conducted in the presence of a trained interviewer, which included questions about feeding methods and pouch use. Parents were encouraged to ask for clarification on questions that they were unsure about or did not understand. Pouches were defined as squeezable containers with a plastic spout. Given the lack of research on pouched foods, several questions were asked to explore frequency, type, method of feeding, contribution to overall diet and proportion of a pouch feed in a single sitting. Parents who feed their infant pouches "5 to 6 times a week", "once a day", or "more than once a day" were defined as frequent pouch feed users. Data was collected on "ready-to-eat versus "home filled" pouch frequency and the extent to which infants were fed these directly or by spoon.

Classification of BLW versus TSF was determined by how often the infant was spoon-fed and how often the infant fed themselves from 6 months to the time of data collection. "Spoon feed by an adult" and "mostly spoon-fed by an adult, some baby feeding themselves" was classified as TSF. "About half spoon-feeding by an adult and half baby feeding themselves" was classified as partial BLW, and "mostly baby feeding themselves, some adult spoon feeding" or "baby feeding themselves" was classified as full BLW.

3.3.7. Data entry

FoodWorks is a software that allows for the analysis of dietary intake. Total, free and added sugar were analysed using FoodWorks v.10 (Xyris, 2020) which uses data from current FOODfiles (Plant and food research, 2018), and food composition data generated by the Department of Human Nutrition at the University of Otago. New foods that were not located within the FoodWorks database were entered using the food nutrition information panel. If the food nutrition panel did not contain micronutrient values, the most comparable food found within the FOODfiles was selected. Mean, and standard deviation was used to report intake of energy and macronutrients. Nutrients and energy were described in grams, kilojoules, and percentage of energy intake.

A total of 2000 foods were classified into 32 food groups. The process in which these foods were classified was based around food components as well as individual ingredients. The largest ingredient component in meals was used to define the food group in which that meal was classed. Food groups that significantly contributed to the total, free and added sugars were then identified. Foods were classified as commercial, mixed, or not commercial. Commercial foods were defined as foods marketed explicitly towards infants. Mixed foods were classified as foods that had a commercial and non-commercial component, for example, pouched foods mixed with home cooked vegetables.

3.3.8. Food group categorisation and descriptions

Based on the foods found within the data set, 32 individual food groups were established. Some foods tend to be consumed as meals consisting of multiple components, while other foods are commonly consumed as individual ingredients; this was considered when grouping certain foods and keeping others as separate food groups. For example, fruit is commonly consumed on its own, so it was coded separately; bread tends to be consumed with other ingredients, so it was coded as "bread-based dishes" instead of "bread". As this study focuses on total, free and added sugar intake, many categories were defined by "sweet" or "savoury". For example, "snack foods-savoury" and "snack foods-sweet". Sweet foods tend to have a higher total, free, and added sugar composition were therefore categorised separately. Descriptions of food groups are outlined in Table 3.1.

Table 3.1. Description of food groups

Food group	*Description*
Grain and pasta dishes	Rice (boiled, fried, risotto, sushi, salad), flour, pasta/noodles, bran, cereal-based products, and dishes (pasta and sauce, lasagne, pasta salad, noodle soup, chow mein)
Bread based dishes- sweet	Includes bead-based dishes with sweet spreads/ toppings/ contents
Bread based dishes- savoury	Includes bead-based dishes with savoury spreads/toppings/contents,
Breakfast cereals- plain	All unsweetened cereals (muesli, wheat biscuits, porridge, puffed/flaked/extruded cereals)
Breakfast- sweetened	Includes all breakfast cereals with fruit, infant formula, sugar added
Nut butter	All nut butter (peanut, almond, cashew butter etc.)
Sweet baked goods	All cakes and muffins, slices, pancakes, doughnuts, pastry
Crackers- savoury	Crackers, crackers with savoury toppings
Cheese	Cheddar, Edam, speciality (blue, brie, feta, etc.), ricotta, cream cheese, cottage cheese, processed cheese
Yoghurt- plain	Greek, plain, and natural yoghurt (unsweetened)
Yoghurt- sweet	Yoghurt with flavour added coconut yoghurt

Yoghurt- with fruit	Yoghurt with fruit included or added
Eggs and egg dishes	Poached, boiled, scrambled, and fried eggs, omelettes, self-crusting quiches, egg stir-fries, fritters without meat/seafood
Mixed dishes- meat	Lamb, beef, poultry, pork, processed meats, and other meats (excludes meat dishes with grains and pasta)
Mixed dishes- fish and seafood	All fish (fresh, frozen, smoked, canned, battered, fingers, etc.), shellfish, squid, crab, fish/seafood dishes (pies, casseroles, and fritters), fish/seafood products
Vegetables	All vegetables (fresh, frozen, canned) including mixes, coleslaw, tomatoes, green salads, legumes and pulses, legume products and dishes (baked beans), vegetable dishes. Includes avocado
Potato, kumara and taro	Mashed, boiled, baked potatoes and kumara, hot chips, crisps, hash browns, wedges, potato dishes (stuffed, scalloped potatoes), taro roots and stalks
Snack foods- savoury	Corn chips, popcorn, extruded snacks (burger rings etc.), grain crisps, rusks
Fruit	All fruits (excluding avocado)
Sugar and sweets	Ice blocks, confectionery, chocolate
Pouched foods-meat/mixed	Pouches with meat, meat and vegetables, vegetables and fruit
Pouched foods- sweet	Pouches with fruit, pouches with sweet ingredients (excluding sweet vegetables)
Pouched foods- savoury	Pouches with vegetables, pouches with savoury ingredients only (excluding pouches including meat)
Sweet beverages	Smoothies, juice, milkshakes, cordial, soft drinks
Other milk	Cows milk, alternative milk (almond, soy oat)
Condiments	Sauces, spreads, nutritional yeast, hummus
Water	Tap and bottled water-unflavoured
Fruit and vegetable mix	Includes fruit and vegetable purees, dishes including only fruit and vegetables
Dishes vegetarian/meat alternatives	Vegetarian meals (excluding vegetarian meals with grains or pasta and meals including only vegetables and fruit)
Baby rice	Includes all baby rice- plain and flavoured
Sweet snacks	Snacks with fruit and sweet flavours

Custard	All custards

3.3.9. Statistical analysis

All of the nutrients were adjusted for "usual intake" using the multiple source method (MSM), which adjusts for within-person variability, except for added and free sugars (Harttig, Haubrock, Knüppel, & Boeing, 2011). This is because several babies had zero free and added sugars. Adjustments for usual intake assume they are habitual consumers of the nutrients, which they likely are not. Values for free and added sugars are the means of the infants two diet recall days. Following nutrient adjustments, statistical analysis was conducted using the SPSS statistical software package (IBM Corp, 2020). Descriptive statistics (participant characteristics, energy and macronutrient intakes, total/free/added sugar intake by food group, feeding practice and pouch use) were defined using frequencies of categorical data. All continuous variables were presented as means ± standard deviation, medians, percentiles (25^{th} and 75^{th}) and ranges (minimum and maximum values). Total, free and added sugar were mostly presented as medians and percentiles as the data were not normally distributed. This method of statistical analysis was undertaken to describe the total, free and added sugar intake of the infants and to identify the major food sources contributing to the infant sugar intake. Furthermore, descriptive statistics were used to determine the contribution of commercial infant foods to infant sugar intake. Inferential statistical tests were run for feeding practice and pouch use to define whether there was a difference in total, free and added sugar between the groups. These statistical tests included the Kruskal-Wallis test of significance which determined if a significant relationship existed based on P values. P values equal to or less than 0.05 showed a significant relationship. In cases where the P value determined a significant relationship, an additional statistical test was run. This test was the Dunn-Bonferroni test of significance which defined where the relationships lay. This method of statistical analysis was undertaken to describe the differences in total free and added sugar intake by baby led weaning, pouch use and the traditional approach to complementary feeding.

3.4. Results

3.4.1. Characteristics of the study participants

Participant characteristics are shown in Table 3.2. The mean infant age was 8.6 months, 55% were male, and two thirds (66.8%) were NZ European. Infants had a healthy mean BMI Z score of 0.35. Half of the infants were firstborn (54%). Most participants fit within the medium NZ deprivation category; the remaining participants were evenly split between low (29.9%) and high (23.2%) deprivation categories, and 1.4% of participants were not categorised. The mean parent age was 33yrs, and the majority were NZ European (66.8%).

Table 3.2. Characteristics of study participants (N = 211)

Characteristics	*Mean ± SD*	*N (%)*
Infant age (months)	8.6 ± 0.85	
Parent age (years)	33.0 ± 4.7	
Infant weight (kg)	8.86 ± 1.27	
Infant length (cm)	70.8 ± 3.3	
Infant BMI Z score [a]	0.35 ± 1.08	
Sex of infant		
Male		117 (55.5)
Female		94 (44.6)
Ethnicity of infant		
NZ European		123 (58.3)
Māori		41 (19.4)
Pasifika		10 (4.7)
Asian		21 (10.0)
Other		16 (7.6)
Ethnicity of parent [b]		
NZ European		141 (66.8)
Māori		25 (11.9)
Pasifika		6 (2.8)
Asian		17 (8.1)
Other		22 (10.4)
Parity [c]		
Primiparous		113 (54)
Multiparous		98 (46)
NZ deprivation category [d]		
Low		63 (29.9)
Medium		93 (44.1)
High		49 (23.2)
unanswered		3 (1.4)

Note:

[a] BMI Z score= measures of relative weight adjusted for child age and sex (BMI= Body Mass Index)

[b] Ethnicity is parents self-selected main ethnicity (other = unspecified)

[c] Parity= number of babies. Primiparous= one child Multiparous= multiple children

[d] NZ deprivation category- low= scores 1-3 medium= scores 4-7 high= scores 8-10 (Atkinson J, 2019)

3.4.2. Dietary analysis of energy and macronutrient intake

The mean ± standard deviation (SD) and median (25th, 75th percentile) energy and macronutrient intakes from foods and beverages consumed are presented in Table 3.3. The mean daily energy intake of the infants (N= 211) was 1436.6kJ; carbohydrates had the highest contribution to total energy intake (46.7%), followed by fat and protein, respectively (33%, 16%). The mean total sugar intake was 16.9g contributing 19.7% of energy intake. The SD for free and added sugars was higher than the mean, suggesting the data is skewed and better represented by the median values. The median free sugar intake was 0.5g per day slightly higher than added sugar (0.2g per day).

Table 3.3. Mean intake of energy and macronutrients (carbohydrates, protein, fat, sugar, and dietary fibre) from complementary foods and beverages

Nutrient	*N*	*Mean ± SD*	*Median (25th, 75th percentile)*	*Range*	
				Minimum	*maximum*
Energy (kJ) [a]	211	1436.6 ± 879.0	1268.3 (789.3, 1987.8)	76.9	5477.6
Carbohydrate (g) [b]	211	40.1 ± 26.4	37.0 (22.3, 54.9)	2.2	186.4
Carbohydrate (kJ)	211	670.5 ± 441.5	618.6 (372.9, 917.9)	36.8	3116.6
Carbohydrate (%E) [c]	211	46.7 ± 30.7			
Total sugar [a] *(g)*	211	16.9 ± 11.0	15.8 (8.9, 23.1)	1.2	93.3
Total sugar (kJ)	211	282.6 ± 183.9	264.2 (148.8, 386.2)	20.1	1560.0
Total sugar (%E)	211	19.7 ± 12.8			
Free sugar (g)	211	1.9 ± 3.4	0.5 (0.9, 2.0)	0	28.5
Free sugar (kJ)	211	31.8 ± 56.9	1.0 (15.1, 33.4)	0	476.5
Added sugar (g)	211	1.5 ± 3.1	0.2 (0.0, 1.5)	0	27.5
Added sugar (kJ)	211	25.1 ± 51.8	3.3 (0.0, 25.1)	0	459.8
Dietary fibre (g)	211	6.7 ± 3.8	6.3 (3.9, 8.6)	0.6	21.2
Total fat (g)	211	12.6 ± 9.6	10.7 (5.2, 17.6)	0.5	53.6
Fat (kJ)	211	474.0 ± 361.2	204.5 (195.6, 662.1)	18.81	2016.4
Fat (%E)	211	33.0 ± 25.1			
Protein (g)	211	13.7 ± 9.4	12.0 (6.3, 18.6)	0.7	51.0
Protein (kJ)	211	229.1 ± 157.2	200.6 (105.3, 311.0)	11.7	852.7
Protein (%E)	211	16.0 ± 10.9			

Note:
[a] kJ= kilojoules
[b] g= grams
[c] %E= percentage of energy intake

[d] Total sugar= sucrose, fructose, maltose, lactose, galactose (all intrinsic and free sugars)

3.4.3. Traditional spoon feeding, partial baby led weaning, and baby led weaning

Infant total, free and added sugar intake by feeding practice are displayed in Table 3.4. The highest proportion of infants followed BLW (38.9%); the ratio of those following partial BLW and TSP were similar, 32.2% and 28.9%, respectively. The median total sugar was the highest for infants following partial BLW (18.21g) and similar for TSP and BLW (~15g). There were significant differences between feeding practices for median free and added sugar, all of which intakes fell below 1g. Table 3.5. displays adjusted P values calculated using the Dunn-Bonferroni post hoc test to determine where the relationship were found. BLW and TSP had significantly different values of free sugar (P value= 0.032). BLW and partial BLW, and BLW and TSP both had significantly different values of added sugar (P value= 0.029 and 0.004 respectively)

Table 3.4. Median grams of total, free and added sugar intake by feeding practice

Feeding practice	*N*	*Total sugar*	*Free sugar*	*Added sugar*
TSP	61	15.31 (7.32, 21.32)	0.83 (0.22, 2.46)	0.58 (0.05, 2.13)
Partial BLW	68	18.21 (10.56, 26.04)	0.53 (0.12, 2.38)	0.45 (0.02, 1.57)
BLW	82	15.49 (9.38, 23.09)	0.37 (0.02, 1.58)	0.09 (0.00, 0.91)
P-value (significance) [a]	-	0.109	0.035	0.003

Note:

[a] *Kruskal-Wallis test of significance*

Table 3.5. Significant relationships between feeding method and sugar intake using adjusted P values

Type of sugar	*Significant relationship*	*Adjusted P-value* [a]
Free sugar	BLW and TSP	0.032
Added sugar	BLW and Partial BLW	0.029
	BLW and TSP	0.004

Note:

[a] *Dunn-Bonferroni test of significance (Kruskal-Wallis post Hoc test)*

3.4.4. Pouch use

Median values of sugar intake are displayed in Table 3.6 Just over half of the infants were partial pouch users (50.2%); the proportions of frequent pouch users and non-pouch users were similar (25.6% and 24.1% respectively). Total, free and added sugar intake was highest for frequent pouch users and lowest for non-pouch users. There were significant differences between median values of total and free sugar and added sugar intake for frequent, partial, and non-pouch users. Table 3.7. displays adjusted P values calculated using the Dunn-Bonferroni post hoc test to determine where the relationship were found. There was a significant relationship between non-pouch user and frequent pouch users for all sugars.

Table 3.6. Median grams of total, free and added sugar intake by frequency of pouch use

Frequency of pouch use	*N*	*Total sugar*	*Free sugar*	*Added sugar*
Frequent pouch user	54	19.89 (9.29, 26.51)	1.59 (0.37, 4.94)	1.19 (0.03, 3.42)
Partial pouch user	106	15.70 (10.30, 22.69)	0.48 (0.06, 1.46)	0.24 (0.00, 1.19)
Non-pouch user	51	10.58 (6.53, 17.39)	0.25 (0.02, 0.86)	0.08 (0.00, 0.86)
P-value (significance) [a]	-	0.001	0.00	0.018

Note:

[a] *Kruskal-Wallis test of significance*

Table 3.7. Significant relationships between frequency of pouch use and sugar intake using adjusted P values

Type of sugar	*Significant relationship*	*Adjusted P-value* [a]
Total sugar	non-pouch users and partial pouch users	0.04
	non-pouch users and frequent pouch users	0.00
Free sugar	non-pouch users and frequent pouch users	0.02
	partial pouch users and frequent pouch users	0.04
Added sugar	non-pouch users and frequent pouch users	0.01

Note:

[a] *Dunn-Bonferroni test of significance (Kruskal-Wallis post Hoc test)*

3.4.5. Total, free and added sugar intake of infants by food group

Values of total, free and added sugar are presented in grams consumed per food group, as seen in Table 3.8. Food groups containing median total sugar intakes above 5g were custards (9.87g), sweet pouches (9.71g) and yoghurt with fruit (7.76g). Fruit and sweetened breakfast contributed 4.98g and 3.56g grams, respectively.

The food groups that contributed the most to median free sugar intake were custard (5.58g), yoghurt with fruit (2.18g), sweet yoghurt (0.31g), sweet snacks (0.26g) and sweet beverages (0.21g). Of these foods, sweet snacks were consumed the most (n= 48), followed by yoghurt with fruit (n=35). Other food groups with a median free sugar intake above zero included sugar and sweets, sweet bread-based dishes, plain breakfast cereals, sweet baked goods, sweet breakfast cereals and savoury crackers.

The food groups from which the infants had the highest intakes of added sugar were custard (5.58g), yoghurt with fruit (2.18g), sweet bread-based dishes (0.13g), plain breakfast cereal (0.12g) and sweet baked goods (0.08g). Of these foods, sweet baked goods were consumed the most (n= 54), followed by yoghurt with fruit (n=35). Other food groups with a median added sugar intake of above zero included sweet breakfast cereals and savoury crackers.

Table 3.8. Median total, free and added sugar intake by food group

Food group	*N*	*Total sugar*	*Free sugar*	*Added sugar*
Grain and pasta dishes	94	0.88 (0.15, 2.68)	0.00 (0.00, 0.13)	0.00 (0.00, 0.01)
Bread based dishes- sweet	16	1.22 (0.23, 2.46)	0.17 (0.00, 0.68)	0.13 (0.00, 0.51)
Bread based dishes- savoury	116	0.77 (0.30, 1.70)	0.00 (0.00, 0.08)	0.00 (0.00, 0.08)
Breakfast cereals- plain	21	1.07 (0.19, 3.10)	0.12 (0.00, 0.29)	0.12 (0.00, 0.29)
Breakfast- sweetened	101	3.56 (1.90, 6.42)	0.06 (0.00, 0.29)	0.01 (0.00, 0.29)
Nut butter	5	0.33 (0.08, 0.37)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Sweet baked goods	54	1.76 (0.67, 3.16)	0.11 (0.00, 2.22)	0.08 (0.00, 2.22)
Crackers- savoury	54	0.08 (0.06, 0.21)	0.06 (0.3, 0.14)	0.06 (0.03, 0.14)
Cheese	51	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Yoghurt- plain	25	0.68 (0.51, 1.60)	0.00 (0.00, 0.06)	0.00 (0.00, 0.00)
Yoghurt- sweet	11	0.52 (0.31, 2.60)	0.31 (0.06, 1.32)	0.00 (0.00, 1.32)
Yoghurt- with fruit	35	7.76 (2.98, 11.90)	2.18 (0.00, 8.46)	2.18 (0.00, 8.46)
Eggs and egg dishes	70	0.37 (0.16, 1.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Mixed dishes- meat	137	0.83 (0.12, 2.56)	0.00 (0.00, 0.12)	0.00 (0.00, 0.02)
Mixed dishes- fish and seafood	38	0.06 (0.00, 0.35)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Vegetables	169	1.18 (0.42, 2.76)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Potato, kumara and taro	83	0.42 (0.05, 1.98)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Snack foods- savoury	107	0.18 (0.06, 0.40)	0.00 (0.00, 0.30)	0.00 (0.00, 0.03)

Fruit	182	4.98 (2.01, 9.75)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Sugar and sweets	21	0.24 (0.17, 0.76)	0.18 (0.08, 0.00)	0.00 (0.00, 0.00)
Pouched foods- meat/mixed	58	2.91 (1.16, 5.09)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Pouched foods- sweet	61	9.71 (5.81, 14.74)	0.00 (0.00, 0.01)	0.00 (0.00, 0.01)
Pouched foods- savoury	34	2.43 (0.98, 4.10)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Sweet beverages	15	3.44 (1.51, 5.48)	0.21 (0.00, 0.58)	0.00 (0.00, 0.58)
Other milk	3	0.70 (0.00, 9.66)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Condiments	16	0.01 (0.00, 0.46)	0.00 (0.00, 0.01)	0.00 (0.00, 0.01)
Water	186	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Fruit and vegetable mix	13	4.37 (2.87, 6.05)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Dishes vegetarian/meat alternatives	18	1.00 (0.24, 2.59)	0.00 (0.00, 0.06)	0.00 (0.00, 0.06)
Baby rice	22	2.74 (0.95, 5.33)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Sweet snacks	48	0.37 (0.16, 1.39)	0.26 (0.00, 0.56)	0.00 (0.00, 0.06)
Custards	5	9.87 (9.18, 9.87)	5.58 (4.73, 8.46)	5.58 (4.73, 8.46)

3.4.6. Sugar intake of infants consuming commercial, mixed, and non-commercial foods

Median values of the total, free and added sugar intake of infants of commercial, mixed, and non-commercial foods are displayed in Table 3.9. All but one infant consumed non-commercial foods, while the majority (70.6%) consumed commercial foods, and one third consumed mixed foods (31.8%). Values of total, free and added sugar are presented in grams. Total sugar intake was the highest in non-commercial foods (9.74g) and lowest in commercial foods (3.41g). Free sugar intake in infants was the highest for non-commercial foods (0.25g), followed by commercial foods (0.17g). Infants fed mixed foods had the lowest free sugar intake (0.00g). Median added sugar intake was low for commercial and mixed foods, and both had a median value of zero grams. Non-commercial foods had a greater median value at 0.14g.

Table 3.9. Median total, free and added sugar intake of infants of commercial, mixed and non-commercial foods

Food type	*N*	*Total sugar (g)*	*Free sugar (g)*	*Added sugar (g)*
Commercial	149	3.41 (0.54, 9.47)	0.17 (0.00, 0.55)	0.00 (0.00, 0.02)
Non-commercial	210	9.74 (4.07, 16.81)	0.25 (0.01, 1.20)	0.14 (0.00, 1.02)
Mixed	67	5.18 (1.80, 8.60)	0.00 (0.00, 0.29)	0.00 (0.00, 0.15)

3.5. Discussion

These results report the total, free, and added sugar intake of seven to ten-month-old infants in New Zealand from complementary foods. This study specifically highlights the differences in free and added sugar intake from food sources, feeding practices, pouch use and commercial and non-commercial foods. As results were taken from a subset of the total infants from the First foods study, it does not represent population values of the total, free, and added sugar intake. It is important to note that many of the infants investigated in this study were NZ European, and the majority fell within the medium deprivation category.

3.5.1. Comparison of results to recommendations

This study reports nutrient intakes of infants from complementary foods. Nutrients from breast or formula milk are not included in the analysis. Carbohydrate intake ranged from 2.2g/d to 186.4g/d, with only 30% of infants meeting the recommended adequate intake (AI) of 51g/d from complementary foods (National Health and Medical Research Council, 2015). The potential implications of infants not meeting their carbohydrate requirements is hindered or slowed, growth and development (National Health and Medical Research Council, 2006).

These study results show infants were consuming 50% less total sugar from complementary foods than infants in the USA (16.9g vs 57g/d and 38.5g/d) (Grimes et al., 2015; Sharma et al., 2013). This may be associated with a 22%-53% variance in energy intake between studies (where Infants overseas were consuming more). Many guidelines suggest total sugar relative to energy intake yet do not recommend how much sugar is appropriate as an independent value. For example, the WHO guidelines advise a maximum sugar intake <10% of energy intake and <5% for better health (excluding intrinsic sugars). For this reason, it is difficult to determine how much sugar is too much. These study results suggest that a higher energy intake may be associated with a higher total sugar intake (and a lower energy intake may be associated with a lower total sugar intake). The infants that fell into the highest 10% of total energy intake had a mean energy intake of 3177kj and a mean total sugar intake of 27.8g. Comparatively, infants that fell into the lowest 10% of total energy intake had a mean energy intake of 275kj and a mean total sugar intake of 3.8g.

Added sugar intake was low, with 79% of infants consuming under 2g per day. Of the infants, 25% (N=52) did not consume any added sugar and thus followed the MoH guidelines. Katiforis (2021) showed a small presence of added sugars in CACFs sold within NZ; therefore, it is not surprising that the majority of infants within this study were consuming above zero grams. Infants in this study consumed similar amounts of added sugar to a previous study on NZ infants, who consumed 0.9-1.2g/d (Williams Erickson et al., 2018). Comparatively, infants overseas consume higher amounts of added sugars, at 4g/d (Foterek et al., 2015).

Based on the median energy intake of 1437kJ, all but one infant consumed <5% of energy from free sugar (<4.2g), while 96% (N=202) were consuming <2.5% of energy from free sugars (<2.1g) This algins with SACN guideline stating Intake of free sugars “should be reduced and minimised with a desirable goal of <5% energy intake in children and adolescents aged ≥2 to 18 years. Intake should probably be even lower in infants and toddlers <2 years” (Fidler Mis et al., 2017). Padarath (2020) investigated free sugar composition, finding the presence of free sugars in 34% of CACFS sold within NZ. In this study, a median value of 0.17g/d of free sugar was found from infant intake of commercial foods, suggesting although some commercial foods contain added sugar, the actual value tends to be low.

3.5.2. Food sources

The most common foods consumed in this study were fruit, vegetables, meat dishes, savoury bread-based dishes, savoury snack foods and sweetened breakfast foods. Most “sweet breakfasts” were sweet due to the addition of fruit (intrinsic sugars), and only a small proportion had free or added sugar. These commonly consumed foods align with the MOH guidelines which recommend first foods to be vegetables, fruit, grain foods, milk products, nut butters, eggs, fish, seafoods and lean red meat (Ministry of Health, 2021).

The food group from which the infants had the highest intakes of total sugar was custard, which was consumed by five infants. Excluding custards, the food groups with the highest sugar content were all fruit-based or included fruit (e.g., pouched foods sweet, yoghurt with fruit, fruit and breakfast-sweetened). Fruit is a nutrient dense food – this is a criteria for complementary foods because they provide a high amount of nutrients per kilojoule of energy (Heyman & Abrams, 2017). Aside from ‘yoghurt with fruit’, these had low free and added sugar (below 1g). This suggests that infants are consuming sugars from intrinsic sources, which are not associated with health risks such as dental caries (Masson et al., 2010).

The MoH guidelines state that “successful food introduction has to overcome the infant’s aversion to new eating experiences” and “taste influences food acceptance”. Many of the food sources consumed were sweet. Repeated exposure to these sweet foods may further ingrain an infant’s innate preference for sweet flavours (Fewtrell, Bronsky, Campoy, Domellöf, Embleton, Fidler Mis, et al., 2017). A much lower number of foods were savoury (not sweet). Many infant food manufactures include sweet vegetables or fruit to mask the bitter flavours of vegetables. Research suggests that infants are less likely to consume bitter foods if the infant is not exposed to the flavour early on (Forestell, 2017).

The majority of the foods eaten by the infants did not contain free sugar (Table 3.6.) Intake of added sugar from custard and yoghurt with fruit was over 2g. The highest Intake of free sugars per day was from custards (Median= 5.58g). The 2% of infants that consumed custard consumed more free and added sugar from a single food item than most other infants had over a day. If more infants were consuming custards, this would be of concern. Yoghurt with fruit was consumed by 17% of infants and contributed a median intake of 2.18g of free and added sugar per day. Yoghurt with fruit was grouped in this study to include yoghurt that was fruit flavoured and yoghurt with fresh fruit added. Yoghurt is a good source of protein; however, plain yoghurt with no added sugar (or plain yoghurt with the inclusion of fresh fruit) should be encouraged over sweetened yoghurt. The MoH guidelines recommend full-fat yoghurt with no added sugar (Ministry of Health, 2021).

3.5.3. BLW, Partial BLW and TSP

Based on these results, feeding practice does not affect free and added sugar intake. The difference between free and added sugar intake for TSP, partial BLW and BLW was minimal. All feeding practices showed an intake of less than 1g/d. No significant differences were found between feeding practices and total sugar intake. TSP infants and BLW had similar total sugar intake (15.31g and 15.47g respectively), while partial BLW had the highest by ~3g (18.21g). Total sugar intake was low among all feeding practices compared to other studies (Grimes et al., 2015; Sharma et al., 2013). Given free and added sugar intakes were low, total sugar intake is likely to have come predominantly from foods high in carbohydrates, such as the foods recommended by the MoH (vegetables and fruit, grain foods, milk products) Fruit and vegetables contain nutrients that support health and growth. Research has shown consumption of these nutrient-dense foods in infancy leads to higher consumption later in life (Rose et al., 2017; Savage, Fisher, & Birch, 2007).

The current MoH guidelines recommend TSP; however, these results suggest that BLW and partial BLW do not negatively affect infant sugar intake. To promote BLW, other nutrient intakes also need to be taken into consideration, e.g., iron and zinc.

3.5.4. Pouch use

Infants that were frequent pouch users showed the highest intake of total sugar. This is not surprising considering the recent findings from Katiforis (2021), where pouched foods contained considerably more total sugars than other forms of commercial infant foods (Katiforis et al., 2021). Infants who were frequent pouch users also had the highest free and added sugar consumption despite pouches sold within NZ containing little to no free or added sugar (Katiforis et al., 2021). This suggests that frequent pouch use may influence eating behaviour. Pouched foods are smooth in texture and easy to consume, meaning an infant is likely to consume a larger portion of the pouch before satiety signaling occurs. Infants who consume pouches are thus likely to have a higher overall energy consumption as well. To further support this hypothesis, infants who were non-pouch users were found to have the lowest intake of total, free and added sugars as well as the lowest energy intake. The mean energy intake of non-pouch fed infants was 1244kj versus 1521kj in frequently pouch fed infants.

3.5.5. Commercial, mixed and non-commercial foods

All food contributed minimal free and added sugar, suggesting that, on average, infant consumption closely aligns with the MoH guideline to prepare or give pre-prepared foods without added sugar (Ministry of Health, 2021). Non-commercial foods were consumed by all but one infant in this study and had the highest contribution to total sugar intake. Carbohydrate foods contain sugars and thus contribute to total sugar intake. Higher total sugar intake (and low free and added sugar intake) in this case may be positive, as 70% of infants were not meeting the AI for carbohydrates from complementary foods. There are two defined AI's for infant carbohydrate intake, one takes milk intake into consideration while the other is created for complementary foods only. As infants in this study are at the age of weaning, and milk intake is not considered, it is difficult to determine if infants are meeting the AI for carbohydrates in their complete diet. Manufactures of infant foods appear to create foods void of, or low in, free and added sugar.

Non-commercial foods had a higher total sugar content than commercial foods suggesting that parents are feeding their infants a greater amount of non-commercial foods and/or providing their infants non-commercial foods that are higher in carbohydrates contributing to total sugar, e.g., breads, cereals, fruit. Commercial and non-commercial foods were predominantly sweet and may hinder an infant's ability to learn and experience new flavours such as bitter and savoury.

These findings provide an incentive for food manufacturers to produce infant foods that are savoury (not sweet) and encourage parents to expose their infants to bitter-tasting foods and reduce their infant's intake of pouched foods. Parents should also be encouraged to increase their infant's intake of carbohydrate-rich foods that are low in free and added sugar to meet the AI of 51g/d. Further investigation will be completed using the entire dataset from the First Foods study (625 infants), which will help develop further understanding of the sugar intake of NZ infants.

3.5.6. Strengths

Currently, there is very little evidence concerning the total, free and added sugar intake of NZ infants. A significant strength of this study was that it provided insight into what sugars infants are consuming and how they are consuming them during the complementary feeding phase. These findings contribute valuable information required to assess whether sugar intake in babies is a topic of interest regarding the health of NZ infants, and more specifically, whether NZ infants adhere to national guidelines.

The data collection method was another major strength, in which dietary information was collected through extensive and detailed interviewing by a trained researcher. Prior to the interview, participants were asked to take pictures of all foods fed to the infant. These pictures were then sent to the researcher to use during the dietary recall. Most participants took photos on their phones, which meant the time and place of the meal could be identified- this helped the participants to remember foods in chronological order and bring up any foods that may not have been photographed. The pictures and prompts and measuring tools were used as well as a three-stage approach of recall to increase the accuracy of the record. The Countdown website was also used to specify brands, weights and types of foods (flavour, low sugar etc.). Food recipes, brands and specific amounts consumed were all documented. Following the recall, a different researcher quality checked the dietary record, and any forgotten or missing details were answered through further contact with the participant. Furthermore, the parent completed the main study questionaries in the presence of a trained interviewer. This meant that clarity could be provided, and any confusion could be discussed and answered accurately thereafter. The dietary records were held on non-consecutive days, and on a different day of the week to the first recall. This meant routine foods consumed on a single given day were avoided.

The mean weight of the infants (8.6 ± 0.85kg) was another strength. As the recommended NRV value for carbohydrates is based on a reference weight of 9kg, the intake of complementary foods could be accurately compared (National Health and Medical Research Council, 2015). To further strengthen the results from this study, milk intake could be calculated and compared against complementary food intake.

3.5.7. Limitations

A major limitation of this study was the use of a convenience sample, data was analysed from 211 participants from the First foods study. The sample was relatively small and it would be worth repeating the analysis in all of the participants from the First Food study. Although the ethnic and deprivation index group percentages were similar to the general population, the number of participants within the ethnic groups was too small to compare. Most of the infants were NZ European and classified as from medium deprivation and thus, this data is most likely to represent this population group only. New Zealand is a multi-ethnic population, and around half of the population falls within low and high deprivation categories. It may be useful to assess the association of sugar intake to specific population groups. By breaking down the infant population, potential predictors such as age, ethnicity, deprivation category and BMI Z score could be identified. Another limitation was the reliance on the infant caregivers to provide accurate information on infant intake.

Unlike Katiforis (2020), this study did not adjust foods entered into the database (FoodWorks) to fit the definitions used by USDA for added sugars and WHO for free sugars. This was justified by the vast number of foods being entered, and the time it would take to make these alterations. Based on the adjustments made by Katiforis (2020), (free sugar correction up to 2g/100g, added sugar correction up to 20g/100g), added sugar may be higher than documented in this study.

3.6. Conclusion

In this study infants consumed sugar primarily from fruit-based foods and sweet vegetables. Most infants consumed minimal amounts of free and added sugars, with median intakes of 0.5g/d and 0.2g/d. Foods of concern from which the infants had the highest intakes of free and added sugars were custards and yoghurt with fruit. Total sugar intake across all infants, between feeding practice, pouch use and commercial and non-commercial foods was low and the majority of infants were not meeting the adequate intake of 51g/d for carbohydrates. Feeding practice and pouch use were significantly related to intakes of total sugar, where partially BLW infants had the highest intakes. Infants that were frequently pouch fed had the highest intake of total, free and added sugar. Interestingly, frequently pouch fed infants had a higher intake of free and added sugars, despite pouched foods containing little to no free and added sugar. The consumption of food from pouches may be associated with eating behaviour and intake of other foods containing free and added sugar.

3.7. Conflicts of interest

The authors declare no conflicts of interest.

Chapter 4: Conclusions and Future Recommendations

4.1. Study summary and achievement of aims and objectives

This cross-sectional, observational study was designed to provide insight into total, free and added sugar intake of NZ infants aged seven to ten months. Eligibility for study participants was that the infants parents (N=211) were aged sixteen years or older and able to speak fluent English. The data used in this study was a subset of data from the First Foods study, which included all participants with two dietary recalls and two questionnaires completed by August 2021. Data on infant age, weight, length, BMI Z-score, sex, ethnicity, parity and deprivation index, and parent age and ethnicity was collected via the health and demographic questionnaire. Data on feeding practice and pouch use was obtained through the main study visit questionnaire, completed in the presence of a trained interviewer.

The primary objective of this study was to describe the quantity of total, free and added sugar intake of the infants. Overall intakes of total, free and added sugar were low compared to infant intake overseas. The MoH guidelines advise against any intake of free and added sugar, thus infants exceeded recommendations, however, free and added sugar intake was minimal, and total sugar intake was of an acceptable quantity. The secondary objective was to describe the major food sources of the total, free and added sugars in the infants' diets. Major foods source were identified and those contributing the largest amount of total sugars were fruit based. Food sources most commonly consumed were those recommended by the MoH guidelines i.e. fruit and vegetables. This research highlights a few key foods sources that may be negatively impacting infant health due to high levels of free and added sugar. Free and added sugars presented high from custards and yoghurt with fruit. It is important to note that these foods were not made for consumption, or advertised as being for infants. The major food groups contributing to infant sugar intake were not from commercially available complementary foods.

The tertiary objective was to determine the contribution of commercial infant foods to total, free, and added sugars intake. Commercial foods were commonly consumed by the infants in this study and contributed less total sugar than non-commercial foods. Findings show many commercial foods consumed by infants are fruit based or contain sweet vegetables. These results build on research of Katiforis (2021) and Padarath (2020) describing commercial foods currently available in NZ.

Mixed foods which consisted of both commercial and non-commercial foods had the second highest total sugar intake. Free and added sugar intake was low among all forms of food. Manufactures of commercial foods are thus adhering to the MoH guidelines, as are parents, when preparing foods for their infants.

The final objective was to describe the differences in total, free and added sugars intake by BLW, pouch use, and a traditional approach to complementary feeding. Partial BLW infants had a slightly higher total sugar intake, and all feeding methods had low free and added sugar values. Partial BLW infants were infants who had experienced the traditional approach to feeding with aspects of the newly popularised BLW. Given partial BLW encompasses both methods of feeding, this research can neither support or discourage the use of BLW regarding sugar intake. Infants who were frequently pouch fed had the higher total, free and added sugar intake than infants who were occasionally pouch fed and infants that were never pouch fed.

4.2. Impact, findings and concluding remarks

This study contributes valuable and novel information on intake of NZ infants for total, free and added sugar combined. Furthermore it describes how popular feeding practices such as BLW and pouch feeding affect sugar intake. As this data comes from a subset of participants from the First Foods study, the sample size is relatively small. The total dataset will be reviewed once the First Foods study is completed in mid 2022. Based on the 2018 census data, the ethnic breakdown of infants within this study somewhat represented that of the general population, as did the distribution of participants across different socio-economic backgrounds. These results are most likely to be indicative of sugar intake of middle-class, NZ European infants.

4.3. Strengths

The current evidence on total, free, and added sugar intake of NZ infants is limited. This observational study describes total, free and added sugar intake of infants from two regions of New Zealand. Furthermore it explores how feeding practices may influence sugar intake. The findings provide valuable data on infant intake during complementary feeding. This study allows for comparison of intake to infant feeding guidelines. The National Health and Medical Research Council uses a reference weight of 9kg, on which the NRVs (nutrient reference values) are created for macronutrients. Within this study the mean infant weight was 8.6 ± 0.85kg, which meant the carbohydrate AI value could be used and equitably compared to infant intake (National Health and Medical Research Council, 2015).

Another major strength was the data collection method, in which dietary information was collected through extensive and detailed interviewing by a trained researcher. This involved a three-stage approach in which pictures, prompts and measuring tools were used to increase the accuracy of the record. Prior to the interview, participants were asked to take pictures of all foods fed to the infant before and after the eating occasion, which heavily decreased the chance of forgetting any foods and allowed for a fairly accurate estimation of how much was actually eaten. Details of food including brands, cooking methods, types, flavours etc. were all recorded. Before the dietary recalls were entered into the database, a quality check was carried out by a different researcher and any missing details were followed up. The dietary records were held on non-consecutive days, and on a different day of the week to the first recall. This meant routine foods consumed on a single given day were avoided. Furthermore, the main study questionnaire was completed during the visit, and the researcher was able to clarify and explain questions that were not clear.

The software 'Foodworks' in which foods were entered into and analysed has undergone a recent update. This update allowed for the free and added sugar intake of the infants to be calculated, as well as total sugar. FoodWorks uses data from current FOODfiles, and food composition data generated by the Department of Human Nutrition at the University of Otago and foods not found within the database were entered using the food nutrition information panel. This meant a thorough analysis of infant intake could be completed and no foods were excluded.

4.4. Limitations

The use of a convenience sample was a major limitation. The data used was a subset from the more extensive First foods study, where participants with completed twenty-four hour recalls were selected. For this reason, the sample was relatively small and should be treated as exploratory. The sample was predominantly made-up of NZ Europeans and participants that fell within the medium deprivation category. Considering that New Zealand is a multi-ethnic population, and that around half of the population falls within low and high deprivation categories, this sample spread is a major limitation. Furthermore, the feeding patterns and foods fed to infants from different ethnic groups may be under-represented in this study. Another limitation was the reliance on the infant caregivers to give accurate recalls of infant intake. Although great measure was taken to ensure accuracy of the dietary recalls, Exact amounts of each food consumed may not be 100% accurate.

This study did not make adjustment to foods entered into FoodWorks, to fit the definitions used by USDA for added sugars and WHO for free sugars. FoodWorks has the ability to calculate free and added sugars, however in some recipes it cannot be determined if the sugar was naturally present or added by the manufacturer. Based on the adjustments made by Katiforis (2020), (free sugar correction up to 2g/100g, added sugar correction up to 20g/100g), added sugar may be higher than documented in this study.

4.5. Recommendations for Future studies

A larger sample size would allow for data to then be statistically inferred on the NZ infant population and potentially validate findings of total, free and added sugar intake of infants from this exploratory study. Although this study identified the food sources, feeding practice, pouch use and commercial versus non-commercial foods in which total, free and added sugar are derived it does not assess the association of sugar intake to specific population groups. Potential predictors of total, free and added sugar intake such as age, ethnicity, deprivation category and BMI Z score, could be identified through further analysis of the data. For example, exploring sugar intake of infants at 7, 8 and 9 months rather than compiling data using a mean age. Studies could also build on this research by addressing the long-term effects of total, free and added sugar as well as the consumption of sweet tasting foods, on health outcomes. Findings could then initiate or drive future interventions such as guideline updates and public health messages. For example, promoting the exposure of savoury or bitter foods, in particular, those foods currently recommend as first foods for infants (vegetables, cereals and wholegrains).

Appendices

Appendix A: twenty four hour Dietary recall sheet

First recall ☐
Second recall ☐

FIRST FOODS
— New Zealand —

Participant ID: ____________ Interviewer: ____________

Date: ____________ Day of the Week: ____________

O-15: 24-hr recall recording sheet

1. Was baby unwell yesterday?	☐ NO	☐ YES
1a. If unwell, did this influence baby's appetite?	☐ NO	☐ YES

QUICK LIST

☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________
☐ ____________

Yes No	**Is salt added to any foods or drinks that baby eats (including on days not covered by the 24 hour recall)? If yes .. what foods/ drinks**
Yes No	**Is sugar added to any foods or drinks that baby eats (including on days not covered by the 24 hour recall)? If yes .. what foods/ drinks**
Yes No	**Is baby offered any drinks other than breast milk, formula, or water (things like cow's milk, other milk, juice, soft drinks, tea, alcohol or any other drink)?**

Version 2: 8Jun 2020 - 1

Participant ID: ____________ Interviewer: ________________

Date: ____________ Day of the Week: ________________

DETAILED 24-H RECALL

Time	Place	Description of Food/Drink	Brand	Amount		Fed by		Pouch used?			
			State the brand or 'brand unknown' (commercial food) or 'homemade'	Amount offered	Amount eaten	Adult	Baby	No	Yes		
									Baby fed self directly	Adult fed baby directly	Adult fed baby from spoon

Participant ID: ______________ Interviewer: ____________________

Date: ______________ Day of the Week: ____________________

RECIPES

Participant ID: ____________ Interviewer: ________________

Date: ____________ Day of the Week: ________________

NOTES

IS FURTHER FOLLOW UP NEEDED?	☐ NO	☐ YES
RESOLVED?	☐ NO	☐ YES

Extreme concern about completeness of recall: ☐ NO ☐ YES

Appendix B: Foods fed by other adults form

First Foods NZ

Foods Fed by Other Adults Diary

FIRST FOODS
— New Zealand —

"Other Caregiver" name: ______________ Date: __________

Caregiver's role (e.g., family member, Early Childhood Centre staff): ____

If Early Childhood Centre staff, please state name of centre:

____

_________________ is involved in a study looking at what and how babies eat. We would really appreciate it if you could write down a complete description of what s/he eats today while in your care, following the instructions on the next page. Your help in completing this diary will provide information so that health professionals and policy makers can advise parents and whānau on how to introduce solids safely to their babies.

FIRST FOODS
— New Zealand —

We know how busy it can be looking after little ones – thank you very much for filling out the information on these pages. We really appreciate your support of the parents' participating in this study. If you would like to know more about the First Foods NZ study, our website is www. http://www.firstfoods.co.nz/.

If you have any comments or questions, then feel free to contact the study on 021 279 0553 or dunedin@firstfoods.co.nz.

O-12 – Version 5: 20 July 2020

Recipes

Step 6: Please record the full recipe and number of portions it makes

Here's an example of how to fill out the food diary:

Step 1	Step 2			Step 3	Step 4		Step 5			
					Food was put in baby's mouth by:		Was food from a baby food pouch?			
							No	Yes, how was food from pouch fed?		
Time & Place	Food name	Food brand	Cooking method	Amount eaten	Adult	Baby		Baby fed self directly from pouch	Adult fed baby directly from pouch	Adult fed baby from spoon
10 am Floor	Apple, pear and berries squeeze pouch	Watties		1 pouch (120 g)		✓		✓		
	Orange flavoured fruit drink	Raro		¾ cup	✓		✓			
12 noon Highchair	Lasagne – See Recipe	Homemade		1 portion	✓	✓	✓			
	Potato		boiled	¼ cup		✓	✓			
	Peas		boiled	10 peas		✓	✓			

We would like you to please:

- **Step 1 & 2**: Write down what food and drink was offered to the child while in your care, and write the time of the day and place they were served these items. Please list each food or drink item individually (e.g., 'bread' 'cheese' instead of 'cheese on toast') and remember to include all water, breast milk and infant formula as well.

- **Step 3**: **Estimate** how much food and drink s/he has **EATEN (this might be less than they were offered)**. You can use household measures (e.g., cups or spoons), sizes of packets (e.g., 140g yoghurt pottle, 15g "Kids" bar).

- **Step 4**: Tick the option that best describes who put the food in his/her mouth. You can tick both options if it was a combined effort (like when you guide the spoon to their mouth but they help push the spoon in).

- **Step 5**: Tick to indicate whether food was from a baby food pouch. If yes, tick the option that best described how baby was fed food from the pouch. *Note*: *baby fed directly from pouch* means baby held pouch and sucked through pouch nozzle, *adult fed baby directly from pouch* means adult held pouch and baby sucked through pouch nozzle.

- **Step 6**: If any foods eaten are recipes, please attach a copy of the recipe to this sheet, including the number of portions the recipe makes. Then in the "amount eaten" column, please record how many of these portions s/he ate e.g., ½ a portion or 2 portions.

Food diary:

Step 1	Step 2			Step 3	Step 4		Step 5			
Time & Place	Food name	Food brand	Cooking method	Amount eaten	Food was put in baby's mouth by:		Was food from a baby food pouch?			
							No	Yes, how was food from pouch fed?		
					Adult	Baby		Baby fed self directly from pouch	Adult fed baby directly from pouch	Adult fed baby from spoon

Appendix C: study overview

Instruments

- Two-day twenty-four hour diet recalls
- FoodWorks software (version 10, 2020, Xyrus Software, Queensland, Australia)

Recruitment

- Convenience sampling through advertising on social media websites (Facebook, Twitter)
- New Zealand
- Participant group: Parents of seven to nine point nine-month-old infants
- Exclusion criteria: parents who could not speak English, parents under sixteen years of age

Study design

- observational cross-sectional design

Data collection

- Food records obtained from the study participant by a trained interviewer for every food and beverage consumed by the infant over a twenty-four hour period (midnight to midnight)
- Sociodemographic data and feeding method information collected via online questionnaire

Statistical analysis

- Analysis of participant sociodemographic information
- Analysis of nutritional intake of study infants using FoodWorks, analysed in SPSS

Completion

- Thesis completion by March 2022

References

ABC Packaging Direct. (2017). Baby food, From jar to pouch: the evolution of packaging. Retrieved from https://cdn2.hubspot.net/hubfs/70169/reports/BABY%20FOOD%20PACKAGING%20REPORT.pdf?t=1516696274002

Atkinson, J., Salmond, C., & Crampton, P. (2014). NZDep2013 index of deprivation. *Wellington: Department of Public Health, University of Otago*.

Atkinson J, S. C., Crampton P. (2019). NZDep2018 Index of Deprivation,. Retrieved from https://www.otago.ac.nz/wellington/otago730394.pdf

Basu, S., Yoffe, P., Hills, N., & Lustig, R. H. (2013). The relationship of sugar to population-level diabetes prevalence: an econometric analysis of repeated cross-sectional data. *PLoS One, 8*(2), e57873.

Beauregard, J. L., Bates, M., Cogswell, M. E., Nelson, J. M., & Hamner, H. C. (2019). Nutrient content of squeeze pouch foods for infants and toddlers sold in the United States in 2015. *Nutrients, 11*(7), 1689.

Birch, L. L., & Doub, A. E. (2014). Learning to eat: birth to age 2 y. *The American Journal of Clinical Nutrition, 99*(3), 723S-728S. doi:10.3945/ajcn.113.069047

Boven, N., Exeter, D., Sporle, A., & Shackleton, N. (2020). The implications of different ethnicity categorisation methods for understanding outcomes and developing policy in New Zealand. *Kōtuitui: New Zealand Journal of Social Sciences Online, 15*(1), 123-139.

Brown, A., & Lee, M. (2015). Early influences on child satiety-responsiveness: the role of weaning style. *Pediatric obesity, 10*(1), 57-66.

Butte, N. F., Fox, M. K., Briefel, R. R., Siega-Riz, A. M., Dwyer, J. T., Deming, D. M., & Reidy, K. C. (2010). Nutrient intakes of US infants, toddlers, and preschoolers meet or exceed dietary reference intakes. *Journal of the American Dietetic Association, 110*(12), S27-S37.

Cameron, S. L., Heath, A.-L. M., & Taylor, R. W. (2012). Healthcare professionals' and mothers' knowledge of, attitudes to and experiences with, baby-led weaning: a content analysis study. *BMJ open, 2*(6).

centers for disease control and prevention. (2020). *infant and toddler nutrition*. Retrieved from https://www.cdc.gov/nutrition/infantandtoddlernutrition/foods-and-drinks/foods-and-drinks-to-limit.html

Cogswell, M. E., Gunn, J. P., Yuan, K., Park, S., & Merritt, R. (2015). Sodium and sugar in complementary infant and toddler foods sold in the United States. *Pediatrics, 135*(3), 416-423.

Coulthard, H., Harris, G., & Emmett, P. (2010). Long-term consequences of early fruit and vegetable feeding practices in the United Kingdom. *Public health nutrition, 13*(12), 2044-2051.

Critch, J. N., Society, C. P., Nutrition, & Committee, G. (2014). Nutrition for healthy term infants, six to 24 months: An overview. *Paediatrics & child health, 19*(10), 547.

D'Auria, E., Bergamini, M., Staiano, A., Banderali, G., Pendezza, E., Penagini, F., . . . Peroni, D. G. (2018). Baby-led weaning: what a systematic review of the literature adds on. *Italian Journal of Pediatrics, 44*(1), 49.

Daniels, L., Heath, A.-L. M., Williams, S. M., Cameron, S. L., Fleming, E. A., Taylor, B. J., . . . Taylor, R. W. (2015). Baby-Led Introduction to SolidS (BLISS) study: a randomised controlled trial of a baby-led approach to complementary feeding. *BMC pediatrics, 15*(1), 1-15.

Dietary Guidelines for Americans 2020-2025. (2020). Retrieved from https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf#page=31

DiNicolantonio, J. J., & Berger, A. (2016). Added sugars drive nutrient and energy deficit in obesity: a new paradigm. *Open Heart, 3*(2), e000469.

Environmental Health Indicators New Zealand. (2020). Oral health of children. Retrieved from https://www.ehinz.ac.nz/assets/Factsheets/Released_2020/OralHealthOfChildrenReleased042020.pdf

European commission. (2019). Feeding infants and young children, . Retrieved from https://ec.europa.eu/jrc/sites/jrcsh/files/processed_cereal_baby_food_online.pdf

Fewtrell, M., Bronsky, J., Campoy, C., Domellöf, M., Embleton, N., Fidler Mis, N., . . . Molgaard, C. (2017). Complementary Feeding: A Position Paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) Committee on Nutrition. *Journal of pediatric gastroenterology and nutrition, 64*(1), 119-132. doi:10.1097/mpg.0000000000001454

Fewtrell, M., Bronsky, J., Campoy, C., Domellöf, M., Embleton, N., Mis, N. F., . . . Lapillonne, A. (2017). Complementary feeding: a position paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) Committee on Nutrition. *Journal of pediatric gastroenterology and nutrition, 64*(1), 119-132.

Fidler Mis, N., Braegger, C., Bronsky, J., Campoy, C., Domellöf, M., Embleton, N. D., . . . Lapillonne, A. (2017). Sugar in infants, children and adolescents: a position paper of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition. *Journal of pediatric gastroenterology and nutrition, 65*(6), 681-696.

Food Standards Australia & New Zealand. (2016,). *Australia New Zealand Food Standards Code – Standard 2.9.2 – Food for infants*. Retrieved from http://www.foodstandards.gov.au/thecode/foodstandardscode.cfm

Food standards Australia & New Zealand. (2021). Sugar labelling. Retrieved from https://www.foodstandards.gov.au/consumer/labelling/Pages/Sugar-labelling.aspx

Forestell, C. A. (2017). Flavor perception and preference development in human infants. *Annals of Nutrition and Metabolism, 70*(Suppl. 3), 17-25.

Foterek, K., Buyken, A. E., Bolzenius, K., Hilbig, A., Nöthlings, U., & Alexy, U. (2016). Commercial complementary food consumption is prospectively associated with added sugar intake in childhood. *British Journal of Nutrition, 115*(11), 2067-2074.

Foterek, K., Hilbig, A., & Alexy, U. (2015). Associations between commercial complementary food consumption and fruit and vegetable intake in children. Results of the DONALD study. *Appetite, 85*, 84-90.

Frary, C. D., Johnson, R. K., & Wang, M. Q. (2004). Children and adolescents' choices of foods and beverages high in added sugars are associated with intakes of key nutrients and food groups. *Journal of Adolescent Health, 34*(1), 56-63.

García, A. L., Raza, S., Parrett, A., & Wright, C. M. (2013). Nutritional content of infant commercial weaning foods in the UK. *Archives of Disease in Childhood, 98*(10), 793-797. doi:10.1136/archdischild-2012-303386

Government of Canada. (2015). Nutrition for Healthy Term Infants: Recommendations from Six to 24 Months,. Retrieved from https://www.canada.ca/en/health-canada/services/canada-food-guide/resources/infant-feeding/nutrition-healthy-term-infants-recommendations-birth-six-months/6-24-months.html

Grimes, C. A., Szymlek-Gay, E. A., Campbell, K. J., & Nicklas, T. A. (2015). Food sources of total energy and nutrients among US infants and toddlers: National Health and Nutrition Examination Survey 2005–2012. *Nutrients, 7*(8), 6797-6836.

Harttig, U., Haubrock, J., Knüppel, S., & Boeing, H. (2011). The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. *European journal of clinical nutrition, 65*(1), S87-S91.

Heyman, M. B., & Abrams, S. A. (2017). Fruit juice in infants, children, and adolescents: current recommendations. *Pediatrics, 139*(6).

Horta, B. L., Loret de Mola, C., & Victora, C. G. (2015). Long-term consequences of breastfeeding on cholesterol, obesity, systolic blood pressure and type 2 diabetes: a systematic review and meta-analysis. *Acta paediatrica, 104*, 30-37.

IBM Corp. (2020). IBM SPSS statistics for windows, (Version 27.0). Armonk, NY: IBM Corp.

Katiforis, I., Fleming, E. A., Haszard, J. J., Hape-Cramond, T., Taylor, R. W., & Heath, A.-L. M. (2021). Energy, Sugars, Iron, and Vitamin B12 Content of Commercial Infant Food Pouches and Other Commercial Infant Foods on the New Zealand Market. *Nutrients, 13*(2), 657.

Koletzko, B., Bührer, C., Ensenauer, R., Jochum, F., Kalhoff, H., Lawrenz, B., . . . Zimmer, K.-P. (2019). Complementary foods in baby food pouches: position statement from the Nutrition Commission of the German Society for Pediatrics and Adolescent Medicine (DGKJ, eV). *Molecular and cellular pediatrics, 6*(1), 1-5.

Koletzko, B., Lehmann Hirsch, N., Jewell, J. M., Caroli, M., Rodrigues Da Silva Breda, J., & Weber, M. (2018). Pureed Fruit Pouches for Babies: Child Health Under Squeeze. *Journal of pediatric gastroenterology and nutrition, 67*(5), 561-563. doi:10.1097/mpg.0000000000002061

Koo, Y.-C., Chang, J.-S., & Chen, Y. C. (2018). Food claims and nutrition facts of commercial infant foods. *PLoS One, 13*(2), e0191982.

Ladewig, N. M., Camargo, L. B., Tedesco, T. K., Floriano, I., Gimenez, T., Imparato, J. C. P., . . . Raggio, D. P. (2018). Management of dental caries among children: a look at the cost-effectiveness. *Expert review of pharmacoeconomics & outcomes research, 18*(2), 127-134.

Li, Y., & Wang, W. (2002). Predicting caries in permanent teeth from caries in primary teeth: an eight-year cohort study. *Journal of dental research, 81*(8), 561-566.

Lioret, S., McNaughton, S., Spence, A., Crawford, D., & Campbell, K. (2013). Tracking of dietary intakes in early childhood: the Melbourne InFANT Program. *European journal of clinical nutrition, 67*(3), 275-281.

Luque, V., Escribano, J., Closa-Monasterolo, R., Zaragoza-Jordana, M., Ferré, N., Grote, V., . . . ReDionigi, A. (2018). Unhealthy dietary patterns established in infancy track to mid-childhood: the EU childhood obesity project. *The Journal of nutrition, 148*(5), 752-759.

Mann, J. (2014). The science behind the sweetness in our diets. *World Health Organization. Bulletin of the World Health Organization, 92*(11), 780.

Martin, C. R., Ling, P.-R., & Blackburn, G. L. (2016). Review of infant feeding: key features of breast milk and infant formula. *Nutrients, 8*(5), 279.

Maslin, K., & Venter, C. (2017). Nutritional aspects of commercially prepared infant foods in developed countries: a narrative review. *Nutrition research reviews, 30*(1), 138-148.

Masson, L. F., Blackburn, A., Sheehy, C., Craig, L. C., Macdiarmid, J. I., Holmes, B. A., & McNeill, G. (2010). Sugar intake and dental decay: results from a national survey of children in Scotland. *British Journal of Nutrition, 104*(10), 1555-1564.

Meier, T., Deumelandt, P., Christen, O., Stangl, G., Riedel, K., & Langer, M. (2017). Global burden of sugar-related dental diseases in 168 countries and corresponding health care costs. *Journal of dental research, 96*(8), 845-854.

Mela, D. J., & Woolner, E. M. (2018). Perspective: total, added, or free? What kind of sugars should we be talking about? *Advances in Nutrition, 9*(2), 63-69.

Ministry of Health. (2020a). Annual Update of Key Results 2019/20: New Zealand Health Survey,. Retrieved from https://www.health.govt.nz/publication/annual-update-key-results-2019-20-new-zealand-health-survey

Ministry of Health. (2020b). New Zealand food composition data,. Retrieved from https://www.foodcomposition.co.nz/

Ministry of Health. (2020c). Virtual Diabetes Register (VDR),. Retrieved from https://www.health.govt.nz/our-work/diseases-and-conditions/diabetes/about-diabetes/virtual-diabetes-register-vdr

Ministry of Health. (2021). *Healthy Eating Guidelines for New Zealand Babies and Toddlers (0–2 years old)*. Wellington Retrieved from

https://www.health.govt.nz/system/files/documents/publications/healthy-eating-infosheet-guidelines-for-new-zealand-babies-and-toddlers-0-2-30sep21.pdf
Moding, K. J., Ferrante, M. J., Bellows, L. L., Bakke, A. J., Hayes, J. E., & Johnson, S. L. (2019). Nutritional content and ingredients of commercial infant and toddler food pouches compared with other packages available in the United States. *Nutrition Today, 54*(6), 305.
Morison, B. J., Taylor, R. W., Haszard, J. J., Schramm, C. J., Erickson, L. W., Fangupo, L. J., . . . Heath, A.-L. M. (2016). How different are baby-led weaning and conventional complementary feeding? A cross-sectional study of infants aged 6–8 months. *BMJ open, 6*(5), e010665.
Morton, S. M., Atatoa-Carr, P. E., Grant, C., Lee, A., Bandara, D., Kinloch, J., . . . Kingi, T. (2012). Growing Up in New Zealand: A longitudinal study of New Zealand children and their families. Report 2: Now we are born.
Motee, A., & Jeewon, R. (2014). Importance of exclusive breastfeeding and complementary feeding among infants. *Current Research in Nutrition and Food Science Journal, 2*(2), 56-72.
Murray, R. D. (2017). Savoring sweet: sugars in infant and toddler feeding. *Annals of Nutrition and Metabolism, 70*(Suppl. 3), 38-46.
National Health and Medical Research Council. (2006). *Nutrient Reference Values for Australia and New Zealand,*. Canberra: National Health and Medical Research Council,
National Health and Medical Research Council. (2013). *Infant Feeding Guidelines: Summary,*. National Health and Medical Research Council Retrieved from https://www.eatforhealth.gov.au/sites/default/files/files/the_guidelines/n56_infant_feeding_guidelines_summary_160822.pdf
National Health and Medical Research Council. (2015). Nutrient Reference Values for Australia and New Zealand. Retrieved from https://www.nrv.gov.au/nutrients/carbohydrate
New Zealand Dental Association. (2008). Healthy Smile, Healthy Child: Oral Health Guide for Well Child Providers, . Retrieved from https://www.nzda.org.nz/assets/files/Public/Order_Resources/Healthy_Smile_Healthy_Child.pdf
Nielsen company. (2015). Oh, Baby! Trends in the Baby Food and Diaper Markets Around the World.
nz, b. (2018). A rising tide of type 2 diabetes in younger people: what can primary care do? Retrieved from https://bpac.org.nz/2021/diabetes-younger.aspx
Padarath, S., Gerritsen, S., & Mackay, S. (2020). Nutritional Aspects of Commercially Available Complementary Foods in New Zealand Supermarkets. *Nutrients, 12*(10), 2980.
Plant and food research. (2018). The consise New Zealand food composition tables *FOODfiles.* Retrieved from https://www.foodcomposition.co.nz/downloads/concise-13-edition.pdf
Pomeranz, J. L. (2012). The bittersweet truth about sugar labeling regulations: they are achievable and overdue. *American journal of public health, 102*(7), e14-e20.
Rapley, G., & Murkett, T. (2008). *Baby-led weaning: Helping your baby to love good food*: Random House.
Romieu, I., Dossus, L., Barquera, S., Blottière, H. M., Franks, P. W., Gunter, M., . . . Margetts, B. (2017). Energy balance and obesity: what are the main drivers? *Cancer Causes & Control, 28*(3), 247-258.
Rose, C. M., Birch, L. L., & Savage, J. S. (2017). Dietary patterns in infancy are associated with child diet and weight outcomes at 6 years. *International journal of obesity, 41*(5), 783-788.
Savage, J. S., Fisher, J. O., & Birch, L. L. (2007). Parental influence on eating behavior: conception to adolescence. *The Journal of law, medicine & ethics, 35*(1), 22-34.
Schwartz, C., Scholtens, P. A., Lalanne, A., Weenen, H., & Nicklaus, S. (2011). Development of healthy eating habits early in life. Review of recent evidence and selected guidelines. *Appetite, 57*(3), 796-807.
Schwarzenberg, S. J., & Georgieff, M. K. (2018). Advocacy for improving nutrition in the first 1000 days to support childhood development and adult health. *Pediatrics, 141*(2).

Scientific Advisory Committee on Nutrition. (2018). *Feeding in the First Year of Life,*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725530/SACN_report_on_Feeding_in_the_First_Year_of_Life.pdf

Sharma, S., Kolahdooz, F., Butler, L., Budd, N., Rushovich, B., Mukhina, G. L., . . . Caballero, B. (2013). Assessing dietary intake among infants and toddlers 0–24 months of age in Baltimore, Maryland, USA. *Nutrition journal, 12*(1), 1-7.

Smithers, L. G., Golley, R. K., Mittinty, M. N., Brazionis, L., Northstone, K., Emmett, P., & Lynch, J. W. (2012). Dietary patterns at 6, 15 and 24 months of age are associated with IQ at 8 years of age. *European journal of epidemiology, 27*(7), 525-535.

Stanhope, K. L. (2016). Sugar consumption, metabolic disease and obesity: The state of the controversy. *Critical reviews in clinical laboratory sciences, 53*(1), 52-67.

Taylor R, C. C., Beck K, von Hurst P, Te Morenga L, Daniels L, Haszard J, Meldrum A, McLean N, Cox A, Tukuafu L, Casale M, Brown K, Jones E, Katiforis I, Rowan M, McArthur J, Fleming E, Wheeler B, Houghton L, Diana A, Heath A,. (2021). Nutritional Implications of Baby-Led Weaning and Baby Food Pouches as Novel Methods of Infant Feeding: Protocol for an Observational Study. *JMIR Res Protoc, 10*(4), e29048. doi:10.2196/29048

Thompson, A. L. (2020). Evaluating the pathways linking complementary feeding practices to obesity in early life. *Nutrition Reviews, 78*(Supplement_2), 13-24.

USDA. (2019). *Infant nutrition and feeding,*. Retrieved from https://wicworks.fns.usda.gov/sites/default/files/media/document/Infant_Nutrition_and_Feeding_Guide.pdf

Ventura, A. K., & Worobey, J. (2013). Early influences on the development of food preferences. *Current biology, 23*(9), R401-R408.

Vos, M. B., Kaar, J. L., Welsh, J. A., Van Horn, L. V., Feig, D. I., Anderson, C. A., . . . Xanthakos, S. A. (2017). Added sugars and cardiovascular disease risk in children: a scientific statement from the American Heart Association. *Circulation, 135*(19), e1017-e1034.

Wagner, Y., & Heinrich-Weltzien, R. (2017). Risk factors for dental problems: Recommendations for oral health in infancy. *Early human development, 114*, 16-21.

Walker, R. W., & Goran, M. I. (2015). Laboratory determined sugar content and composition of commercial infant formulas, baby foods and common grocery items targeted to children. *Nutrients, 7*(7), 5850-5867.

Wang, Y., Guglielmo, D., & Welsh, J. A. (2018). Consumption of sugars, saturated fat, and sodium among US children from infancy through preschool age, NHANES 2009–2014. *The American Journal of Clinical Nutrition, 108*(4), 868-877.

Williams Erickson, L., Taylor, R. W., Haszard, J. J., Fleming, E. A., Daniels, L., Morison, B. J., . . . Taylor, B. J. (2018). Impact of a modified version of baby-led weaning on infant food and nutrient intakes: the BLISS randomized controlled trial. *Nutrients, 10*(6), 740.

World Health Organization. (2001). *Report of the expert consultation of the optimal duration of exclusive breastfeeding, Geneva, Switzerland, 28-30 March 2001*. Retrieved from

World Health Organization. (2009). Infant and young child feeding: Model chapter for textbooks for medical students and allied health professionals (Session 3). Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK148957/

World Health Organization. (2015a). Guideline: sugars intake for adults and children. World Health Organization. Retrieved from https://www.who.int/publications/i/item/9789241549028

World Health Organization. (2015b). *Information note about intake of sugars recommended in the WHO guideline for adults and children*. Retrieved from

World Health Organization. (2017). *Sugars and dental caries*. Retrieved from

World Health Organization. (2019). Commercial Foods for Infants and Young Children in the WHO European Region. A study of the Availability, Composition and Marketing of Baby Foods in Four European Countries. *Geneva, Switzerland: Author*.

World Health Organization. (2020). Oral health, . Retrieved from https://www.who.int/news-room/fact-sheets/detail/oral-health

World Health Organization. (2022). Complementary feeding. Retrieved from https://www.who.int/health-topics/complementary-feeding#tab=tab_2

Xyris. (2020). New nutrients/components Retrieved from https://xyris.com.au/whats-new-foodworks-9-professional/