School of Public Health

EARLY CHILDHOOD FEEDING PRACTICES AND DENTAL CARIES IN AUSTRALIAN PRE-SCHOOLERS

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This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

February, 2020

AUTHOR'S DECLARATION

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The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262) [Approval Numbers #SPH-39-2014 (FFQ validation study) and #HR-155/2013 (Curtin reciprocal ethics for SMILE) see Appendix B]; the Southern Adelaide Clinical Human Research Ethics Committee (approval number HREC/50.13) and the South Australian Women and Children Health Network (approval number HREC/13/WCHN/69).

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17/02/2020

ABSTRACT

Background: This topic sits in the nexus between two critical, global public health issues. While breastfeeding is recognised as one of the top interventions for reducing mortality among children under 5 years of age (UNICEF, 2016; Victora et al., 2016), untreated dental caries is the most prevalent chronic health condition globally, and the most common chronic disease among children (Kassebaum et al., 2017; World Health Organization, 2015).

Recent reviews propose a relationship between some breastfeeding practices and increased risk of early childhood caries (ECC) (Cui et al., 2017; Moynihan et al., 2019; Tham et al., 2015), reflecting the long-held clinical consensus among sectors of the dental workforce (Kotlow, 1977; Valaitis et al., 2000). The duration of breastfeeding is an exposure of interest, however the age at which breastfeeding begins to have a detrimental effect on oral health remains unclear (Peres et al., 2018). An association between night-time breastfeeding and higher risk of ECC has also been proposed (Nakayama & Mori, 2015; Tham et al., 2015).

The evidence for these associations is inconsistent; hindered by the small number of cohort studies, most of which have considerable methodological limitations. These limitations include inconsistent definitions and measurement methods, particularly for breastfeeding and other dietary factors, along with inadequate investigation of covariates such as socio-economic position (Moynihan et al., 2019; Peres et al., 2018). To date, it has been difficult to accurately capture free sugars intakes in early childhood, due to the absence of validated dietary assessment tools for this age group (Evans et al., 2013b). In Australia, national dietary surveys exclude 0–2 year-olds, and neither free sugars nor commercial infant and toddler foods were included in the most recent national nutrient database update.

Aims: The primary aim of this research is *to assess the association between 1) prolonged and 2) night-time breastfeeding and early childhood caries*. To achieve this, secondary and tertiary aims emerged, which are: *to develop and assess relative validity of a dietary assessment tool to capture the leading dietary contributors to dental caries risk in Australian toddlers aged 18–30months*; and *to describe the status of free sugars in the diets of a cohort of Australian children aged 0–2 years*.

Methods: Based in Adelaide, South Australia, the longitudinal Study of Mothers' and Infants' Life Events affecting oral health (SMILE) recruited mother-child dyads and triads from maternity hospitals in 2013–14. The Study is investigating a range of factors that shape the oral health of young children; however this thesis focuses only on those relevant to exploring the relationship between breastfeeding practices and ECC, in keeping with the primary aim.

Participants in SMILE underwent a standardised dental examination at 2–3 years of age to determine the prevalence of ECC, based on the presence of decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces. Breastfeeding practices were reported when the child was 3 months, 6 months, 1 year and 2 years of age, and used to determine the age of breastfeeding cessation. Sleep-feeding practices were reported at 1 year of age, including breast, bottle or mixed feeding to sleep, and usual bottle contents (if used).

A directed acyclic graph of causal pathways between breastfeeding and ECC was developed, identifying maternal education and area-level socio-economic position as key confounders, with child's intake of free sugars as a mediator, and fluoride as an effect modifier (Ha et al., 2019; Moynihan et al., 2019; Tham et al., 2015). At the time of recruitment, all children lived in areas with a fluoridated mains water supply, so fluoride was not included in the multivariable models. Socio-demographic characteristics, including maternal education and area-level socio-economic position, were collected at recruitment.

Free sugars intakes were assessed using a 24-hour recall and 2-day estimated food record at 1 year of age, and a newly developed food frequency questionnaire (the SMILE-FFQ) at 2 years. The SMILE-FFQ was designed to assess intakes of total and free sugars from major food and beverage sources in Australian toddlers via proxy report, and was then investigated for relative validity against repeat 24-hour recalls in an external population of Australian toddlers aged 18–30 months (n = 95). Validity testing revealed a mix of good and acceptable agreement for total and free sugars, informing the conclusion that the SMILE-FFQ is acceptable for ranking participants by sugars intakes in observational studies of Australian toddlers. The SMILE-FFQ was then administered to the SMILE cohort at 2 years of age, and a

free sugars variable created, based on compliance with the World Health Organization [WHO] (2015) guidelines for free sugars intakes.

Multivariable regression models generated prevalence ratios (PR) for the association between ECC and breastfeeding duration, and between ECC and sleep-feeding practices at 1 year, controlling for area-level socio-economic position, maternal education, child free sugars intake and age at the time of the dental examination.

The intakes and major food sources of free sugars among the SMILE cohort were also examined, along with socio-demographic determinants of high free sugars consumption and the progression of free sugars intakes from 1 to 2 years of age.

Results: Of the 1039 children who completed the dental examination, early childhood caries was present in 110 (10.6%). Mean breastfeeding duration was 10 months, with 40% of participants still breastfed at 1 year of age. Most of these had ceased breastfeeding by 18 months (14% still breastfed) or 2 years (9%).

There was no independent association between breastfeeding beyond 1 year of age and ECC (PR 1.42, 95% Confidence Interval (CI) 0.85-2.38), or between breastfeeding to sleep and ECC (PR 1.12, 95% CI 0.67-1.88), although the direction of effect was suggestive of an association. The only factors independently associated with ECC were high free sugars intakes (PR 1.97, 95% CI 1.13-3.44), and greater socio-economic disadvantage (PR 2.15, 95% CI 1.08-4.28).

Free sugars intakes appear to have increased from 1 to 2 years of age, however measurement methods differed between the time points and so direct comparisons of free sugars values should be interpreted cautiously. Nevertheless, an overall upward trend was observed, with the proportion of the cohort exceeding the WHO (2015) recommendation that less than 10% of energy should come from free sugars increasing from 2% of the cohort at 1 year to 38% of the cohort at 2 years; and the less than 5% recommendation exceeded by 71% at 2 years, up from 23% at 1 year.

Commercial infant and toddler foods emerged as a major source of free sugars at both time points, contributing 27% of free sugars intakes at 1 year, and 15% at 2 years of age. Other key food sources of free sugars were fruit and vegetable juices and drinks (7% of free sugars at 1 year, 11% at 2 years) sweet biscuits (8% and 7%),

cakes, muffins, doughnuts and cake-type desserts (8% both years) and yoghurts not specifically marketed to infant or toddlers (10% and 9%).

At both ages, socio-economic position was a determinant of high free sugars intake, with children from households with the greatest socio-economic disadvantage more likely to exceed the WHO free sugars recommendations than the least disadvantaged.

Discussion and Conclusions: In this cohort of toddlers, neither the duration of breastfeeding, nor night-time breastfeeding practices at 1 year were associated with early childhood caries. Instead, high free sugars intakes and low socio-economic position presented as key risk factors for ECC.

Only one of the three recent systematic reviews of breastfeeding and ECC explored different durations beyond 1 year of age, finding that caries risk only increased if breastfeeding continued beyond the second year of life, but not if it ceased between 1 and 2 years (Moynihan et al. 2019). Additionally, recent data from the Australian National Oral Health Study observed a higher prevalence and severity of ECC among children breastfed beyond 2 years of age that was only present in subjects without exposure to fluoridated mains water (Ha et al., 2019). These findings partially explain why we did not observe an association between prolonged breastfeeding and ECC in our cohort; who had mostly ceased breastfeeding early in the second year of life and were all living in fluoridated areas at the time of recruitment. Further, the low prevalence of both the primary exposure variable and the outcome variable may have introduced a rare events bias, leading to the relatively wide confidence intervals given the sample size. The results of our study support the continuation of breastfeeding into the second year of life; however, further studies are needed in populations with longer durations of breastfeeding and higher ECC prevalence.

The short- and long-term benefits of breastfeeding in low, middle and high income countries are unequivocal (NHMRC, 2012a; Victora et al., 2016). Within the broader context of a child; their mother; and issues of community and global health, income and equity; the benefits of breastfeeding cannot be understated. In Australia, breastfeeding durations fall short of guidelines, so efforts to increase breastfeeding are likely to improve the overall health of children and adults. Early childhood caries is the only negative health consequence currently linked to breastfeeding in the literature (Victora et al., 2016), and is influenced by a range of dietary and dental risk factors (Peres et al., 2018), some of which appear to mitigate the effect of breastfeeding (Ha et al., 2019)

In light of these findings, population messages about breastfeeding should not be confused by caveats relating to potential caries risk, and dental practitioners are encouraged to support and promote breastfeeding in line with national and international guidelines. Improved efforts are needed to limit intakes of foods high in free sugars, through food regulation and labelling, curbing the influence of food marketing and media, and using fiscal policy to guide purchasing behaviour. Efforts to improve oral health should also be supported, including subsidised access to dental health services, public water fluoridation schemes and the inclusion of oral health into primary health care services. These approaches would be strengthened by actions to reduce health inequality, targeting the social determinants of health.

ACKNOWLEDGEMENTS

The work of this PhD falls within the NHMRC-funded Study of Mothers' and Infants' Life Events affecting oral health. I am grateful to the study team, including the chief investigators for affording me this opportunity, and offering counsel and encouragement along the way. In particular, thank you to Professor Loc Do and Dr Diep Ha, for answering my questions and helping me understand the dental aspects of our research. Thank you also to the study participants, who gave so generously of their time.

Thank you to my primary supervisor, Professor Jane Scott for teaching me that "thank you" is always written as two words, along with some other important things. You were exactly the supervisor I needed, offering leadership, guidance, and space for me to learn, along with compassion and flexibility when things got complicated. Your supervision award in 2019 was highly deserved.

Thanks also to Dr Andrea Begley for your supervision, encouragement and advice; and to Professor Deb Kerr for chairing the thesis committee and fielding my dietary assessment-related questions. Thank you to colleagues who helped me directly and indirectly, including research collaborators Aqif Muktahar, Dr Elinor Ytterstad and Professor Rebecca Golley, and many advisor-encouragers from Curtin School of Public Health, including Janine Wright, Dr Amelia Harray and Dr Kyla Ringrose.

This research is supported by an Australian Government Research Training Program Scholarship.

I would also like to express my gratitude for my incredible network of family and friends; I could not have done this without you. In particular, to the first scientist I ever met; my late grandfather, Peter Hughes, from whom I learned skills in critical thinking, meticulous pedantry and an interest in learning about the world.

Thanks also to the fiercely strong and intelligent women in my life, including my family: Evelyn Hughes, Nola Coleman and Dr Claire Coleman, and my many amazing friends. From you I learned about stoicism, tenacity and courage, and when I grow up I want to be all of you.

Finally, to the late John Coleman, and the always-on-time Neale Devenish-Coleman; thanks for teaching me about kindness and self-compassion, for accompanying me on this crazy ride, and for constantly telling me I would make it.

STATEMENT OF CONTRIBUTORS

This thesis is presented in hybrid format, including peer-reviewed publications and additional unpublished work. Attribution statements for the publications that form the thesis are provided below. Further dissemination activities, including conference presentations and additional publications arising from this research are in 1.6, p. 8. A summary of candidate contributions to the Study of Mothers' and Infants' Life Events affecting oral health is provided in 1.5.1, p. 6.

PUBLICATIONS INCLUDED AS PART OF THE THESIS

Devenish, G., Mukhtar, A., Begley, A., Do, L., & Scott, J. (2017). Development and Relative Validity of a Food Frequency Questionnaire to Assess Intakes of Total and Free Sugars in Australian Toddlers. *International Journal of Environmental Research and Public Health*, 14(11). doi:10.3390/ijerph14111361

Presented in 3.3, commencing page 82.

	Concept & Design	**Acquisition of Data**	**Data Conditioning & Manipulation**	**Analysis & Statistical Method**	**Interpretation & Discussion**	**Final Approval**
Gemma Devenish	X	X	X	X	X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]					
Aqif Mukhtar			X	X		X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]					
Andrea Begley	X				X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]					
Loc Do	X				X	X
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Jane Scott	X			X	X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]					

Devenish, G., Ytterstad, E., Begley, A., Do, L., & Scott, J. (2019b). Intake, sources, and determinants of free sugars intake in Australian children aged 12-14 months. *Maternal & Child Nutrition*, e12692. doi:10.1111/mcn.12692

Presented in 4.3, commencing page 118.

	Concept & Design	Secured Funding	Acquisition of Data	Data Conditioning & Manipulation	Analysis & Statistical Method	Interpretation & Discussion	Final Approval
	X		X	X	X	X	X
Gemma Devenish	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
				X	X	X	X
Elinor Ytterstad	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
	X					X	X
Andrea Begley	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
	X	X				X	X
Loc Do	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
	X	X			X	X	X
Jane Scott	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						

Devenish, G.; Golley, R.; Mukhtar, A.; Begley, A.; Ha, D.; Do, L.; Scott, J. (2019a). Free sugars intake, sources and determinants of high consumption among Australian 2 year olds in the SMILE cohort. *Nutrients*, 11(1), 161, doi:10.3390/nu11010161

Presented in 4.4, commencing page 140.

	Concept & Design	**Secured Funding**	**Acquisition of Data**	**Data Conditioning & Manipulation**	**Analysis & Statistical Method**	**Interpretation & Discussion**	**Final Approval**
Gemma Devenish	X		X	X	X	X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Rebecca Golley	X				X	X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Aqif Mukhtar				X	X	X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Andrea Begley						X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Diep Ha	X	X				X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Loc Do	X	X			X	X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Jane Scott	X	X				X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						

Devenish, G.; Mukhtar, A.; Begley, A.; Thomson, W.M.; Spencer, A.J.; Ha, D.; Do, L.; Scott, J. (2020). Early childhood feeding practices and dental caries among Australian pre-schoolers. *The American Journal of Clinical Nutrition*. doi:10.1093/ajcn/nqaa012

Presented in 5.2, commencing page 168.

	Concept & Design	**Secured Funding**	**Acquisition of Data**	**Data Conditioning & Manipulation**	**Analysis & Statistical Method**	**Interpretation & Discussion**	**Final Approval**
Gemma Devenish	X		X	X	X	X	X
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Andrea Begley						X	X
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W. Murray Thomson	X	X				X	X
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A. John Spencer	X	X				X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Diep Ha	X	X	X			X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Loc Do	X	X	X			X	X
	I acknowledge that these represent my contribution to the above research output Signed: [signature removed]						
Jane Scott	X	X				X	X
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GLOSSARY

This thesis follows current, mainstream terminology for mothers, fathers, parents and breastfeeding. The terms used throughout this document are intended to be understood in their more expansive, inclusive interpretations, in recognition of the diversity of gender and family norms. The candidate acknowledges the limitations of these terms in current use.

Adult Teeth: see *secondary dentition*

Baby Teeth: see *primary dentition*

Biofilm: "an aggregation of microorganisms that attach to each other or a surface, such as a tooth, and enclose themselves in a self-produced extracellular polymeric substance." (Hinds et al., 2016, p. 179)

Breastfeeding: The provision of human milk to a child, including from the mother or other family member, a breast milk donor or a wet-nurse, given via any delivery method, including directly from the breast, or expressed and given via a bottle, cup or feeding tube, or added to complementary foods and beverages (NHMRC, 2012a; WHO, 2008). Refer to Figure 2.4 (p. 62) for the WHO definitions of breastfeeding sub-types.

Breast milk: Human milk, including colostrum, given via any means (NHMRC, 2012a).

Breast-sleeping: bed-sharing while breastfeeding throughout the night (Ball et al., 2019; McKenna & Gettler, 2016)

Caregiver: "A person who gives care to people who need help taking care of themselves. Examples include children, the elderly, or (people with a disability or chronic illness)." (NIH, 2019). In the case of children, this may include parents, other family members, friends, childcare professionals or others as determined by a parent or legal guardian.

Caries balance: The result of ongoing cycling of tooth enamel demineralisation and remineralisation. Prolonged periods of demineralisation shift the caries balance towards disease (see 2.3, p. 15) (Kilian et al., 2016; Seow, 1998).

Cariogenic: promoting dental caries

Carioprotective: protective against dental caries

Child: a person less than 18 years of age (WHO, 2016)

Common risk factor approach: Recognises that a substantial proportion of chronic disease risk is attributable to a shared set of environmental factors and individual behaviours; such that public health policies that target these risk factors may have widespread effects across a range of disease outcomes, and reduce health inequality (Watt et al., 2019; Watt & Sheiham, 2012).

Complementary food: "any nutrient-containing foods or semi-solids, given to infants in addition to breast milk or commercial infant formula" (NHMRC, 2012a, p. 129).

Core food/s: foods that form the basis for a healthy diet, including fruits, vegetables, legumes, whole grains and other cereal products, nuts, eggs, fish, lean meat, milk products and their plant-based alternatives (NHMRC, 2013). See also *energy-dense, nutrient-poor (non-core) foods*.

Demineralisation (tooth): Loss of minerals (such as calcium and phosphate) from body tissues (such as the surface of the teeth) (Featherstone, 2008)

Dysbiosis: "A condition in which the normal microbiome population structure is disturbed, often through external burdens such as disease states or medications" (Kilian et al., 2016, p. 658)

Early Childhood Caries: Also referred to as dental caries, tooth decay, nursing caries (informal), bottle rot (informal), "the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child under the age of six." (AAPD, 2016, p. 60)

Energy-dense, nutrient-poor (non-core) foods: Also referred to as discretionary foods, "This includes foods and drinks not necessary to provide the nutrients the body needs, but that may add variety. However, many of these are high in saturated fats, (added) sugars, (added) salt and/or alcohol... Foods in this category include cakes, biscuits; confectionary, chocolate; pastries, pies; ice confections, butter, cream, and spreads which contain predominantly saturated fats; potato chips, crisps and other fatty or salty snack foods; sugar-sweetened soft drinks and cordials, sports and energy drinks and alcoholic drinks." (NHMRC, 2013, p. 144)

Father: A person who identifies as male and assumes parental responsibility for a child in a shared or sole capacity. This includes any male-identifying adoptive parent/s, and those in step-parenting roles via marriage or de-facto status. A child may have more than one father.

Food Security: "A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." This is observed across four dimensions: "food availability, economic and physical access to food, food utilization, and stability over time" (FAO et al., 2019, p. 186).

Formula: also referred to as breast milk substitute, "a product based on milk or other edible food constituents of animal or plant origin which is nutritionally adequate to serve as the principal liquid source of nourishment for infants." (NHMRC, 2012a, p. 129). Throughout this thesis, the term may also encompass follow-on formula, that is, formula products intended for children older than 1 year of age.

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." (WHO, 2015, p. 5)

Infant: a person less than 12 months (1 year) of age (WHO, 2016)

Inter-professional education: "when two or more professions learn about, from and with each other to enable effective collaboration and improve health outcomes" (WHO, 2010, p. 13)

Mother: A person who identifies as female and assumes parental responsibility for a child in a shared or sole capacity. This includes any female-identifying adoptive parent/s, and those in step-parenting roles via marriage or de-facto status. A child may have more than one mother.

Pre-schooler: a person who has not yet commenced formal schooling; in Australia this is a child less than 5 years of age.

Primary Dentition: also known as deciduous dentition, baby teeth (informal) or milk teeth (informal). The first set of teeth, typically exfoliated in childhood and replaced by secondary dentition (also known as adult or permanent teeth).

Policy Inertia: "the combined effects of inadequate political leadership and governance to enact policies…, strong opposition to those policies by powerful commercial interests, and a lack of demand for policy action by the public." (Swinburn et al., 2019, p. 791)"

Remineralisation (tooth): The reversal of demineralisation, that is, the return of minerals (calcium, phosphorous and fluoride) to the tooth (Featherstone, 2008)

Secondary Dentition: also known as permanent dentition or adult teeth (informal). The final set of teeth, which emerge, typically during childhood, to replace the primary dentition.

Severe Early Childhood Caries: "any sign of smooth-surface caries in a child younger than three years of age, and from ages three through five, one or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of greater than or equal to four (age 3), greater than or equal to five (age 4), or greater than or equal to six (age 5)." (AAPD, 2016, p. 60)

Toddler: a person between 12 and 36 months (1-3 years) of age (NHMRC, 2012a).

Weaning: "The period during which an infant is introduced to breast milk substitute or solid foods, or both, with the intention of ceasing breastfeeding" (NHMRC, 2012a, p. 130)

LIST OF ABBREVIATIONS

24HR	24-Hour Recall
AAPD	American Academy of Paediatric Dentistry
AuAPD	Australasian Academy of Paediatric Dentistry
ABS	Australian Bureau of Statistics
ADA	Australian Dental Association
AIHW	Australian Institute of Health and Welfare
ANZ	Australia and New Zealand
ARCPOH	Australian Research Centre for Population Oral Health
BF	Breastfeeding / Breastfed
CI	Confidence Interval
CSIRO	Commonwealth Scientific Industrial Research Organisation
DAA	Dietitians Association of Australia
DAG	Directed Acyclic Graph
dmft/s	a count of the number of decayed, missing (due to caries), and filled teeth or surfaces (lowercase text refers to primary teeth)
ECC	Early Childhood Caries
EER	Estimated Energy Requirement
EI	Energy Intake
FAO	Food and Agriculture Organization of the United Nations
FFQ	Food Frequency Questionnaire
FSANZ	Food Standards Australia and New Zealand
ICDAS	International Caries Detection and Assessment System
IQR	Interquartile Range
IRSAD	Index of relative socio-economic advantage and disadvantage
MSM	Multiple Source Method
NHMRC	National Health and Medical Research Council (Australia)
NIDCR	National Institute of Dental and Craniofacial Research (US)
NIH & NCI	National Institutes of Health and National Cancer Institute (US)
NOS	Newcastle-Ottawa Scale for assessing study quality
PR	Prevalence Ratio
PHAA	Public Health Association of Australia

SD	Standard Deviation
S-ECC	Severe Early Childhood Caries
SEIFA	Socio Economic Index For Areas
SMILE	Study of Mothers' and Infants' Life Events affecting oral health
SMILE-FFQ	SMILE Food Frequency Questionnaire
US	United States of America
WBTi	World Breastfeeding Trends Initiative
WHO	World Health Organization

Chapter 1 INTRODUCTION

1.1 Overview

This chapter introduces the research activities and reporting methods, starting with a statement of the problem, and outlining research aims and objectives used to address the identified issues. This is followed by a summary of the overall thesis structure with brief chapter descriptions. The Study of Mothers' and Infants' Life Events affecting oral health (SMILE) is then described, including the candidate's contributions to the research. The chapter concludes with a list of dissemination activities undertaken as a result of the work of this thesis.

1.2 Statement of the Problem

There is a clinical consensus in sectors of the dental workforce that some breastfeeding practices increase the risk of Early Childhood Caries (ECC). Study findings in this area are inhibited in their conclusions by design limitations, including inconsistent definitions and data collection methods for the outcome and exposure variables; and inadequate investigation of covariates, particularly free sugars. A prospective birth cohort study is needed to investigate the relationship between breastfeeding practices and ECC, employing a rigorous study design methodology and controlling for key covariates.

The relationship between breastfeeding practices and ECC does not appear to be simply a linear, dose-dependent interaction, so clarification is needed with regard to which aspects of early childhood feeding are carioprotective, which are cariogenic, and which have no impact on caries risk. Some evidence suggests that there may be a u-shaped relationship between breastfeeding duration and ECC risk, with increased ECC associated with less or no breastfeeding to around 6 months of age, no association with breastfeeding into the second year of life, but increased ECC with breastfeeding for prolonged periods (Cui et al., 2017; Moynihan et al., 2019; Tham et al., 2015). The age at which breastfeeding begins to have a detrimental effect on oral health remains unclear (Peres et al., 2018). An association between night-time breastfeeding and higher risk of ECC has also been proposed (Tham et al., 2015).

In order to undertake this investigation, methods for assessing the dietary intakes of young children, particularly free sugars, need to be developed for use with the current, Australian food supply. There is no dietary assessment tool that measures free sugars intake in pre-school aged children that is applicable to the Australian context. During the pre-school years, from birth to around age 5, children traverse a unique food landscape as they learn the skills of eating and develop dietary habits for life, so dietary assessment methods must accommodate the challenges of measuring intakes through this time (Livingstone et al., 2004; Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013). National monitoring surveys have not investigated the dietary intakes of 0- to 2-year-olds, and neither free sugars, nor commercial infant and toddler foods were included in the most recent national nutrient database update. As a result, the free sugars intakes of Australian toddlers is largely unknown.

The harms from early childhood caries are as critical to public health as those from not breastfeeding, and translation of findings must consider the overall health outcomes of each, as well as the common risk factors for chronic disease prevention.

1.3 Research Aims, Objectives and Hypotheses

The primary aim of this thesis is *to assess the association between 1) prolonged and 2) night-time breastfeeding and early childhood caries*. In order to achieve this, a secondary aim was identified, which is *to develop and assess the relative validity of a dietary assessment tool to capture the leading dietary contributors to dental caries risk in Australian pre-schoolers aged 18–30 months*. As a result of the research activities, a tertiary aim emerged; *to describe the status of free sugars in the diets of a cohort of Australian children aged 0–2 years*. The research objectives undertaken to achieve these aims are summarised in Table 1.1, along with relevant study activities and reporting chapters.

Table 1.1 Research objectives and activities

Aim		Objective	Activities	Chapter
1º	1.	Critique the current evidence for the associations between breastfeeding and ECC, in order to ascertain mechanisms of action, likely confounders in the causal pathway and current limitations of research to date	Literature review	2
2º	2.	Develop a dietary assessment tool to assess intakes of total and free sugars from major food and beverage sources, fluoride from non-water sources and other key foods relevant to dental caries in Australian pre-schoolers aged 18–30 months via a proxy report	FFQ development	3
2º	3.	Investigate the relative validity of the tool developed in objective 2, for total sugars, free sugars and fluoride against repeat 24-hour recalls, using external calibration methods	FFQ validation study	3
3º	4.	Investigate intakes and food sources of free sugars at 1 and 2 years of age; compare findings to WHO intake recommendations and national data; and explore socio-demographic determinants of high free sugars consumption.	SMILE	4
1º	5.	Assess the relationship between infant feeding practices and ECC, controlling for key dietary and demographic factors, in a cohort of Australian children experiencing universal fluoride coverage	SMILE	5

1º Primary aim: to assess the association between prolonged and night-time breastfeeding and ECC;

2º Secondary aim: to develop and assess the relative validity of a dietary assessment tool to capture the leading dietary contributors to dental caries risk in Australian pre-schoolers aged 18–30months;

3º Tertiary aim: to describe the status of free sugars in the diets of a cohort of Australian children aged 0–2 years

ECC: Early childhood Caries SMILE: Study of Mothers' and Infants' Life Events affecting oral health WHO: World Health Organization FFQ: Food Frequency Questionnaire

Analysis of the SMILE data under the primary aim will address the following hypotheses:

1. Children who are breastfed for 1 year or longer are at no greater risk of developing ECC than other children (i.e. those never breastfed, breastfed for less than 6 months or between 6 months and 1 year).
2. Children who receive night-time breastfeeds are at no greater risk of developing ECC than other children (i.e. formula fed children who receive night-time feeds or breast or formula fed children who do not receive night-time feeds).
3. Children who consume diets low in free sugars at 1 and 2 years of age have a lower risk of ECC, independent of breastfeeding practices.

1.4 Thesis Structure and Chapter Description

The thesis chapters are mapped to the study aims and objectives in Table 1.1. The thesis begins with foundational investigations into early childhood caries (ECC), including a review of studies on this topic. After the intake of free sugars is identified as an under-utilised covariate in research to date, methods for assessing free sugars in this age group are explored. The sugars intakes of Australian toddlers are largely unknown, so dietary findings from the SMILE cohort are then reported. The narrative then returns to the breastfeeding-ECC relationship, using free sugars data as a covariate in the multivariable analyses, concluding with a translation of findings.

Foundational investigations (chapter two)

In order to address the primary aim, the determinants of ECC were investigated, exploring potential contributions of infant feeding practices to caries pathology, and the deficits of the current evidence base. Chapter 2 critically reviews the literature, and identifies key limitations of recent studies. In particular, the need for validated dietary assessment methods, and robust cohort studies that control for a range of covariates is established. A summary of how SMILE methods build on the strengths and limitations of prior studies concludes the chapter. This chapter meets objective 1 and informs the study methods used in objectives 2-5.

Measurement and reporting of free sugars (chapters three and four)

Chapter 3 describes the methodology for estimating free sugars intakes in the SMILE cohort at 1 and 2 years of age, including the SMILE Food Frequency Questionnaire (SMILE-FFQ). Development and validity testing of the SMILE-FFQ for assessing total and free sugars is reported via publication, followed by additional validity testing of the tool for assessing fluoride (unpublished). The chapter finishes by describing the methods used to administer the SMILE-FFQ to the SMILE cohort at 2 years of age. This chapter meets objectives 2 and 3, and the secondary aim.

Chapter 4 explores the dietary results of the SMILE cohort, presenting free sugars intakes at 1 and 2 years of age. Two publications are included in this chapter, each reporting intakes, major food sources, and determinants of high free sugars consumption at one of the time points. The chapter commences with a brief description of some initial data investigations that informed the methodological decisions in the management of the 1 and 2 year data which were not reported in either publication. This chapter meets objective 4 and the tertiary aim.

Early childhood feeding practices and dental caries (chapter five)

Chapter 5 draws together the outputs from chapters 2-4, in an investigation of associations between infant feeding practices and early childhood caries in Australian pre-schoolers. This chapter is presented via a publication, which meets the primary aim of this work, and delivers objective 5.

Translation of findings (chapter six)

Chapter 6 reviews the thesis objectives in light of the findings, and makes overall conclusions regarding breastfeeding and ECC. A discussion of recommendations for practitioners and for public health action is presented, considering the common risk factor approach to health. The thesis concludes with recommendations for future research in this area.

1.5 The Study of Mothers' and Infants' Life Events Affecting Oral Health

The Study of Mothers' and Infants' Life Events affecting oral health (SMILE) is an NHMRC-funded, longitudinal cohort study in Adelaide, South Australia. The study is led by the Australian Research Centre for Population Oral Health (ARCPOH), in partnership with nutrition researchers at Curtin and Flinders Universities. The overall study aim is "*to identify and evaluate the relative importance and timing of critical factors that shape the oral health of young children and then evaluate those factors in terms of their interrelationship with socio-economic influences"* (Do et al., 2014, p. 2). The study received further funding to follow the children to 7 years of age (SMILE–2), however this thesis covers the initial funding period, which included the first 2 to 3 years of the children's lives.

Participants were recruited from the three major maternity hospitals in Adelaide, South Australia, between July 2013 and August 2014. All new mothers with sufficient English competency and not intending to move out of the greater Adelaide area within one year of recruitment were invited to participate. Hospitals servicing lower socio-economic areas were oversampled to account for the expected higher attrition rates. This resulted in an analysis population that was acceptably representative of the socio-economic profile of South Australian births in 2013 (Scheil et al., 2015). The study population includes 2,147 mothers who gave signed, informed consent to join the study, and their 2,181 newborns, including 34 pairs of twins.

The Southern Adelaide Clinical Human Research Ethics Committee approved the study (approval number #HREC/50.13, approval date: 28 Feb 2013) as did the South Australian Women and Children Health Network (#HREC/13/WCHN/69, approval date: 7 Aug 2013), with reciprocal ethics granted by the Curtin University Human Research Ethics Committee (#HR-155/2013, approval date: 10 Oct 2013; see Appendix B).

Participants were invited to complete questionnaires at recruitment (baseline), and when their child reached 3 months, 6 months, 1 year and 2 years of age. The questionnaires collected information on a range of dietary, dental and socio-demographic risk factors and were available in the participant's choice of online, paper or telephone interview formats. Additional dietary assessment was conducted at the same time as the 1 and 2 year questionnaires, via a 24-hour dietary recall and 2-day estimated food record at 1 year, and administration of the SMILE food frequency questionnaire (SMILE-FFQ) at 2 years of age. The questions from SMILE that provided data used in this thesis are provided in Appendix C.

The study methods are further described in 2.6 (p. 66), with a detailed dietary assessment methodology presented in chapters 3 and 4.

1.5.1 Candidate's Contribution

Table 1.2 summarises the candidate's contributions to SMILE. The candidate developed the SMILE-FFQ and conducted the validity study with support from the co-authors. Around the same time, preparations were underway to administer the 24-hour recalls to the SMILE cohort at 1 year, so the candidate reviewed the suitability of the five step multi-pass method (ABS, 2014b) for use with parents of 1-year-olds, and created supporting materials for use in both the SMILE-FFQ validation and the SMILE 1-year data collection wave. The candidate also assisted with the design and administration of the 2-day food record materials, also administered when the child was 1 year of age.

Table 1.2 Candidate's contribution to SMILE

Study activities	Candidate's contribution	Thesis section
SMILE-FFQ development and validation	Designed SMILE-FFQ, including review of the literature, producing questionnaire content and visual design, and creation of a nutrient database for scoring. Designed the scoring algorithm and oversaw development of the scoring database by consultant AM. Conducted validation study in an external cohort, including study design, ethics approval, participant recruitment, data collection, entry, analysis and reporting (supported by co-authors).	3.3 3.4
SMILE design	1 year dietary assessment: contributed to the design of 2-day food record materials. Led the development of 24-hour recall protocol, conducted training and calibration of interviewers	3.2
	2 year dietary assessment: designed SMILE-FFQ (above). Generated paper and online versions of SMILE-FFQ for SMILE cohort and handed over to ARCPOH research assistant for administration to cohort, providing technical support where needed.	
SMILE data collection and entry	1 year dietary assessment: contributed to the preparation, mailing and receiving of materials and participant follow-up (in partnership with research assistants at Curtin and ARCPOH). Developed the infant foods database, building on data for some foods initially provided by student volunteers. Led the development of the data entry protocol, conducted training and calibration of data enterers. Entered dietary intakes of approx. 10% of participants in first wave, and approx. 60% of participants in second wave (re-entry). Performed data export from FoodWorks, conducted data checking cleaning and transformation. Provided resulting dietary data output to ARCPOH.	3.2 4.2 4.3
	2 year dietary assessment: resolved technical issues with online SMILE-FFQ as needed, provided entry protocol to ARCPOH research assistant for SMILE-FFQ paper version. Designed protocol for invalid responses to SMILE-FFQ paper version. Performed data cleaning and checking of responses, merging online and paper responses. Applied scoring database to responses to generate sugars values, conducting data audit of output. Provided resulting dietary data to ARCPOH.	3.5 4.2 4.4
SMILE data analysis	Completed all data preparation, cleaning and transformation tasks.	4.2
	1 year dietary assessment: performed analyses of free sugars intake and food source data; except for determinant analysis (performed by EY).	4.3
	2 year dietary assessment: performed analysis of free sugars intake and food source and tracking data (advised by YZ and RG); except for determinant analysis (performed by LD).	4.4
	Outcome analysis: performed analysis of Prevalence Ratios in SASS using syntax provided by LD, adapted to this dataset with support by AM.	5.2

ARCPOH: Australian Research Centre for Population Oral Health, AM: Aqif Mukhtar, EY: Elinor Ytterstad, JS: Jane Scott, YZ: Yun Zhao, RG: Rebecca Golley, LD: Loc Do.
(see Statement of Contributors p. xiii for co-author declarations)

The 1 and 2 year dietary data entry, cleaning and preparation for analysis was led by the candidate; for some activities with the 1 year data, the candidate oversaw the work of students volunteering or participating in a Curtin Masters of Dietetics research project; by establishing protocols, providing training and support to the students, and checking the accuracy of the outputs.

The candidate obtained and merged datasets, and transformed data where required (for example, the application of Multiple Source Method to the 1 year data) in preparation for analysis. Statistical support from co-authors allowed the candidate to perform most of the analysis presented in this thesis, with the exceptions of the determinant analysis for free sugars at 1 and 2 years. The candidate was later able to perform similar analyses for the final publication, with support from the co-authors.

1.6 Dissemination and Awards

In addition to the four publications presented within this thesis (see Statement of Contributors, p. xiii), the candidate reported on the research outcomes via presentations at two international and one national conference, as well as two local state seminars and one research seminar in Hawai'i. A further seven publications report on the SMILE dietary data collected at 1 and 2 years of age, for outcomes outside of the work of this thesis. These arose from Curtin University Masters of Dietetics research projects, for which the candidate was primary or secondary supervisor, and one Flinders University honours project, for which the candidate provided assistance with the use of SMILE dietary data.

1.6.1 Conference Presentations

Devenish G, Scott J.A., Begley A, Spencer J, Thomson M, Ha, D. and Do, L. (June 2019) Does sustained breastfeeding cause early childhood caries? [Oral] Presented at the 10th Maternal and Infant Nutrition and Nurture International Conference. Cumbria, United Kingdom. *Maternal and Child Nutrition*, 16: e12933. https://doi.org/10.1111/mcn.12933

Devenish, G., Begley, A., Do, L. & Scott, J. (September 2015). A Food Frequency Questionnaire to assess total sugar intake of Australian toddlers: relative validity and repeatability against repeat 24 Hour recalls [Poster]. Presented at the 9th International Conference on Diet and Activity Methods. Brisbane, Australia.

Devenish, G., Begley, A., Do, L. & Scott, J. (May 2015). What are Australian Toddlers Eating? [Poster]. Presented at the 32nd Dietitians Association of Australia National Conference. Perth, Australia. *Nutrition & Dietetics*, 72 (Suppl 1). doi:10.1111/1747-0080.12181

1.6.2 Seminars and Symposia

Devenish G. (January 2020). Breastfeeding and early childhood caries: A review and update. [Oral]. Presented at the University of Hawai'i Cancer Center, Population of the Sciences Pacific Program – Epidemiology Research Seminar Series. University of Hawai'i at Manoa, Honolulu, Hawai'i.

Devenish G, Mukhtar, A., Begley A, Ha, D., Do, L. and Scott J.A (November 2019) Does sustained breastfeeding cause early childhood caries? [Oral] Presented at the Dietitians Association of Australia WA Symposium. Perth, Australia.

Devenish G, Begley A, and Scott J.A. (September 2018) Free Sugars intakes of Australian children aged 12-14 Months: sources and determinants of compliance with WHO Guidelines. [Oral]. Presented at the Mark Liveris Student Research Seminar. Curtin University, Perth, Australia.

1.6.3 Additional Publications Reporting on SMILE Dietary Data

The following papers use SMILE dietary data and were co-authored during the course of this candidacy:

Bell, L. K., Schammer, C., Devenish, G., Ha, D., Thomson, M. W., Spencer, J. A., Do L. G., Scott J. A., and Golley, R. K. (2019). Dietary Patterns and Risk of Obesity and Early Childhood Caries in Australian Toddlers: Findings from an Australian Cohort Study. *Nutrients*, 11(11), 2828. doi:10.3390/nu11112828

Coxon, C., Devenish, G., Ha, D., Do, L., & Scott, J. A. (2019). Sources and Determinants of Discretionary Food Intake in a Cohort of Australian Children Aged 12–14 Months. *International Journal of Environmental Research and Public Health*, 17(1), 80. doi:10.3390/ijerph17010080

Scott, J., Ahwong, E., Devenish, G., Ha, D., & Do, L. (2019). Determinants of Continued Breastfeeding at 12 and 24 Months: Results of an Australian Cohort Study. *International Journal of Environmental Research and Public Health*, 16(20), 3980. doi:10.3390/ijerph16203980.

Scott, J. A., Gee, G., Devenish, G., Ha, D., & Do, L. (2019). Determinants and Sources of Iron Intakes of Australian Toddlers: Findings from the SMILE Cohort Study. Interna*tional Journal of Environmental Research and Public Health*, 16(2), 181. doi:10.3390/ijerph16020181

Beaton E, Wright J, Devenish G, Do L. Scott J (2018). Relative validity of a 24-hour recall in assessing intake of key nutrients in a cohort of Australian toddlers. *Nutrients*. 10, 80. doi:10.3390/nu10010080

Bell, S.; Yew, S.; Devenish, G.; Ha, D.; Do, L.; and Scott, J. (2018) Duration of Breastfeeding, but Not Timing of Solid Food, Reduces the Risk of Overweight and Obesity in Children Aged 24 to 36 Months: Findings from an Australian Cohort Study. *International Journal of Environmental Research and Public Health*. 15, 599. doi:10.3390/ijerph15040599

Scott J, Davey K, Ahwong E, Devenish G, Ha D, Do L. (2016) A comparison by milk feeding method of the nutrient intake of a cohort of Australian toddlers *Nutrients*, 8, 501. doi:10.3390/nu8080501

1.6.4 Candidate Awards

Best Presentation: *Does sustained breastfeeding cause early childhood caries?* Dietitians Association of Australia WA State Symposium, 2019

Curtin HDR student mobility travel award, 2019. University of Hawai'i Cancer Center, 26 January to 5 February 2020. Primary aim: collaboration with Professor Carol Boushey and other nutrition researchers at University of Hawai'i Cancer Center with the view to translating the SMILE-FFQ into a short screening tool for use by dental and other practitioners in need of a short measure of free sugars intake.

Chapter 2 BACKGROUND: BREASTFEEDING AND EARLY CHILDHOOD CARIES

2.1 Overview

This chapter presents the background to the potential role of breastfeeding practices as a risk factor for early childhood caries (ECC), reviewing the evidence base from the perspectives of both dental and nutrition related health outcomes, and critiquing research methods used to investigate this relationship. The order of information is as follows:

1. Introduction to breastfeeding and ECC.
2. Determinant analysis of ECC, working from the primary interaction pathway outwards, to proximal and then distal determinants.
3. Investigation of whether breastfeeding could be a determinant of ECC, including the potential mechanisms of action, findings from the literature so far (highlighting research gaps), the introduction of fluoride as a potential effect modifier, and the resulting inconsistencies in current practice guidelines.
4. A summary of the current limitations in ECC research to date, followed by explanation of how the work of SMILE addresses these challenges.

This chapter contributes to the primary aim of this work, via objective 1, which is to *critique the current evidence for the associations between breastfeeding and ECC, in order to ascertain mechanisms of action, likely confounders in the causal pathway and current limitations of research to date* (see Table 1.1, p. 3).

2.2 Introduction

This issue falls in the intersection between two critical areas of global public health. The effects of diet quality in the first 1000 days of life are far-reaching, with health and socio-cultural impacts throughout the life course (Schwarzenberg & Georgieff, 2018; Thousand Days, 2019). While the short and long-term benefits of meeting breastfeeding recommendations are unparalleled (National Health and Medical

Research Council [NHMRC], 2012a; Victora et al., 2016), there is evidence to suggest that some breastfeeding practices may increase the risk of ECC (Moynihan et al., 2019; Tham et al., 2015; Victora et al., 2016). Early childhood caries is a global public health problem (WHO, 2017c), the effects of which also follow an individual throughout their life (Colak et al., 2013). Dental caries in the primary (deciduous) teeth is a significant predictor of caries in secondary (permanent) teeth (Colak et al., 2013; Peres et al., 2019; Skeie et al., 2006), and untreated dental caries in secondary teeth is the most common health condition worldwide, affecting 34.1% of the global adult population (Peres et al., 2019). The global disease burden from ECC is substantial, as is that of insufficient breastfeeding (James et al., 2018; NHMRC, 2012a; Victora et al., 2016), therefore any attempts to improve either health outcome need to consider the implications for the other.

2.2.1 Breastfeeding

The Australian Infant Feeding Guidelines for Health Workers (NHMRC, 2012b, p. 3) recommend "exclusive breastfeeding to around 6 months of age", then "continue(d) breastfeeding while introducing appropriate solid foods until 12 months of age and beyond, for as long as the mother and child desire". These Australian Guidelines mirror the WHO (2003b) recommendations in the Global Strategy for Infant and Young Child Feeding, although breastfeeding to 2 years of age and beyond is recommended in the international guidelines.

In Australia, compliance with these recommendations is poor. In the National Infant Feeding Survey, 62.9% of infants were consuming some breast milk at 5 months of age, but only 15.4% were being exclusively breastfed (AIHW, 2011). Despite the benefits of breastfeeding reaching well into the second year of life and beyond, (Victora et al., 2016), breastfeeding duration in Australia falls short, with only 18% of toddlers aged 13-18 months still consuming breast milk (AIHW, 2011).

A 2016 Lancet series on breastfeeding highlighted the unequivocal and wide ranging benefits of breastfeeding in low, middle and high income countries (Victora et al., 2016). If all children achieved current breastfeeding recommendations, a predicted 823 000 deaths per year could be prevented in children under 5 years of age, and a further 20 000 deaths per year from breast cancer prevented in their mothers (Victora et al., 2016). The benefits extend further, beyond reductions in morbidity and mortality, to economic and human capital development (UNICEF & The Global Breastfeeding Collective, 2017). Breastfeeding is a direct contributor to achieving 8 out of the 17 United Nations Sustainable Development Goals, and is linked, less directly, with most others (UNICEF, 2016; Victora et al., 2016). Estimates have placed the global economic cost of not breastfeeding in line with recommendations at about US$341.3 billion per year, or 0.70% of world gross national income (Walters et al., 2019).

The only negative health consequence currently linked to breastfeeding in the literature is early childhood caries (Tham et al., 2015; Victora et al., 2016).

2.2.2 Early Childhood Caries

The definitions of ECC and severe ECC were developed by the American Academy of Pediatric Dentistry (AAPD, 2016) and adopted by the World Health Organization (Phantumvanit et al., 2018; WHO, 2017c). They are:

> "Early childhood caries is defined as the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child under the age of six."
>
> "Severe early childhood caries is any sign of smooth-surface caries in a child younger than three years of age, and from ages three through five, one or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of greater than or equal to four (age 3), greater than or equal to five (age 4), or greater than or equal to six (age 5)."
>
> (AAPD, 2016, p. 60)

Dental caries occurs as the result of an interaction between fermentable carbohydrates, predominantly free sugars, and cariogenic microorganisms in a susceptible tooth and host over a period of time (Colak et al., 2013; Moynihan & Kelly, 2014). This interaction is moderated by a range of interrelated determinants (Figure 2.1, p. 16). ECC has previously been referred to as 'nursing caries', 'comforter caries', 'baby bottle caries' and 'bottle rot', among others; however these terms fail to represent the complex aetiology of the disease, as it also occurs in children who are not bottle fed (Colak et al., 2013; Tinanoff et al., 2019).

Untreated dental caries is the most prevalent chronic health condition globally, and the most common chronic disease among children (WHO, Kassebaum et al., 2017; 2015). There is currently no ongoing monitoring of dental caries in Australia, therefore national prevalence and trend data rely on *ad hoc* surveys (COAG Health Council, 2015). The Australian National Child Oral Health Study, conducted from 2012 to 2014, found that of 41.7% of children aged between 5 and 10 years in the study had caries in their primary teeth (Do & Spencer, 2016). The survey reports a decline in the prevalence of caries in primary teeth since the last national oral health survey (which was in 1987), however analysis of school based child dental service records from 1977 to 2002 suggests that the lowest prevalence of caries occurred in the mid-1990s, and rates are now increasing (Armfield & Spencer, 2008). In addition, severity of caries is clustered by low socio-economic position, with around 20% of children aged between 5 and 10 years experiencing over 80% of the caries burden for their age group in the national survey (Do & Spencer, 2016).

The consequences of ECC are both short- and long-term. Quality of life and general health of infants and children with ECC can quickly diminish as the disease progresses and the associated pain and discomfort increase. ECC can affect how infants and children grow and develop, speak, participate in school, and function socially (Colak et al., 2013; Gussy et al., 2006; Peres et al., 2019). If the decay is severe enough to affect the buccal surfaces of maxillary incisors, facial disfigurement can occur (Harris et al., 2004). ECC may also lead to reduced self-esteem, altered eating and sleeping patterns and acute and chronic infections (Colak et al., 2013). Impacts on the ability to chew and taste food may result in difficulties weaning the infant or toddler; and in older children the avoidance of nutritious foods such as fruit, vegetables and whole grain cereals (Colak et al., 2013; Kantovitz et al., 2006). In young children, insufficient food intake as a result of ECC often leads to reduced growth and insufficient weight gain for age (Colak et al., 2013).

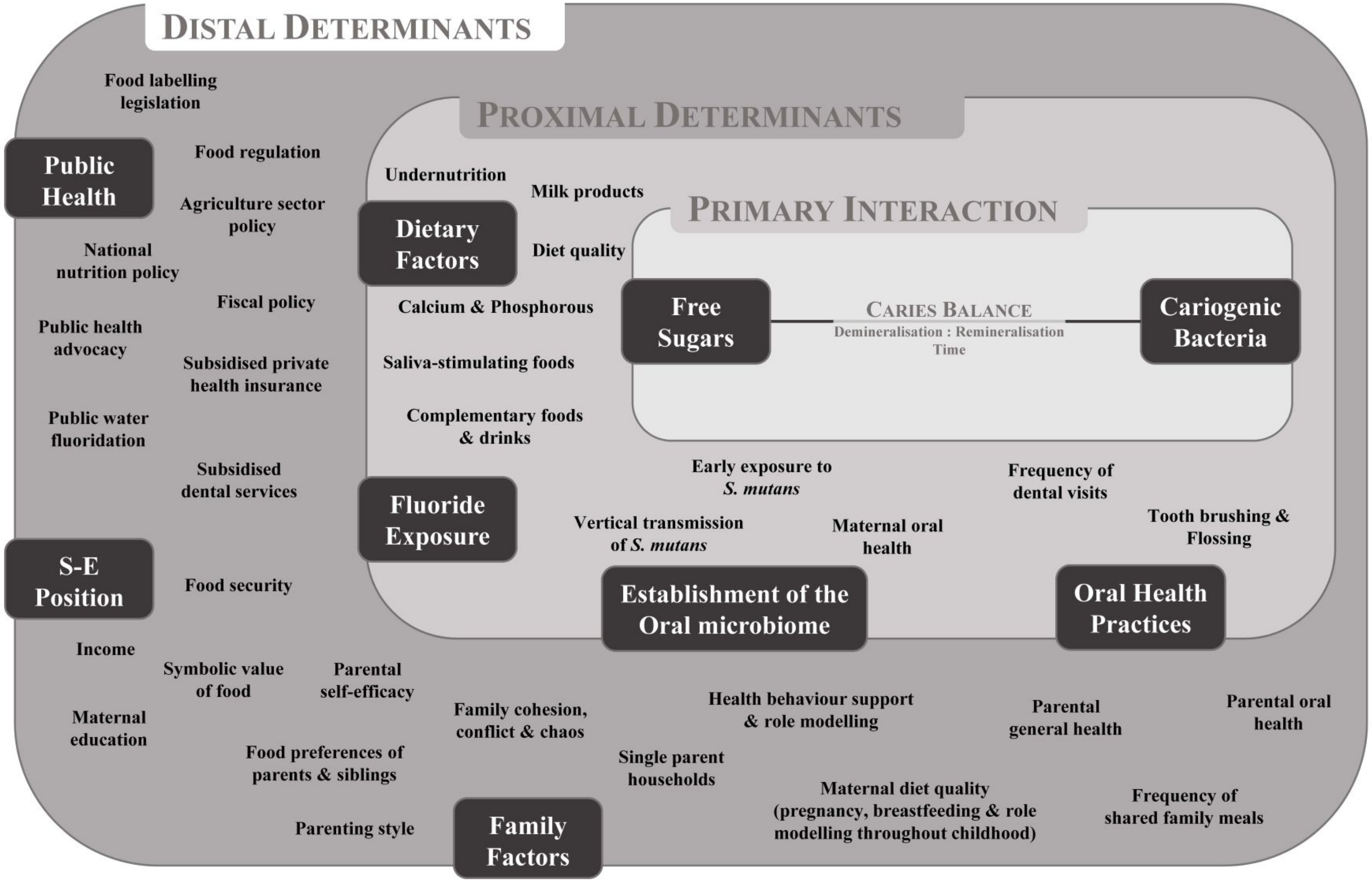
For many children with severe ECC, treatment occurs under a general anaesthetic, which is a leading cause of general anaesthetic-related hospitalisations in children (AIHW, 2012; Gussy et al., 2006). Associated costs put financial strain on families, and the experience may be traumatic for the child and caregivers (Phantumvanit et al., 2018). In Australia, children aged between 5 and 9 years had the highest rate of potentially preventable hospitalisations related to dental conditions than any other age group, followed by adults over 65 years, adults 55 to 64 years, and children 0 to 4 years of age (AIHW, 2019).

The physical and psychological impacts of ECC can continue throughout the life of the individual. Dental caries is a progressive, chronic disease, which, if not treated, leads to infection, sepsis and tooth loss (Colak et al., 2013; Peres et al., 2019). Poor dentition plays a central role in the nutritional status of older adults, with around 20% of adults aged 65 years and older regularly avoiding certain foods due to dental problems (AIHW, 2012). Periodontal diseases are linked with systemic health conditions in adults, particularly cardiovascular disease and diabetes; suboptimal pregnancy outcomes such as pre-term birth and low birthweight; and aspiration pneumonia (Cullinan & Seymour, 2013; Mani et al., 2013). The global direct and indirect costs of dental disease are estimated to be approximately US $544.41 billion per year, with the highest per capita productivity losses and dental expenditures observed in Australasia and High-Income North America (Righolt et al., 2018).

2.3 Determinants of Early Childhood Caries

Healthy teeth undergo cycles of enamel demineralisation and remineralisation throughout the day as a regular part of self-maintenance. Dental caries results from an imbalance in this cycling, with regular periods of excessive demineralisation relative to repair causing decay on the tooth surface (Featherstone, 2008). This ‘caries balance’ (between demineralisation and remineralisation), is a dynamic process, moderated by a wide range of determinants, which can be examined in terms of their proximity to a primary interaction pathway (Figure 2.1). Non-modifiable determinants such as genetic predisposition and salivary constituents are not considered here.

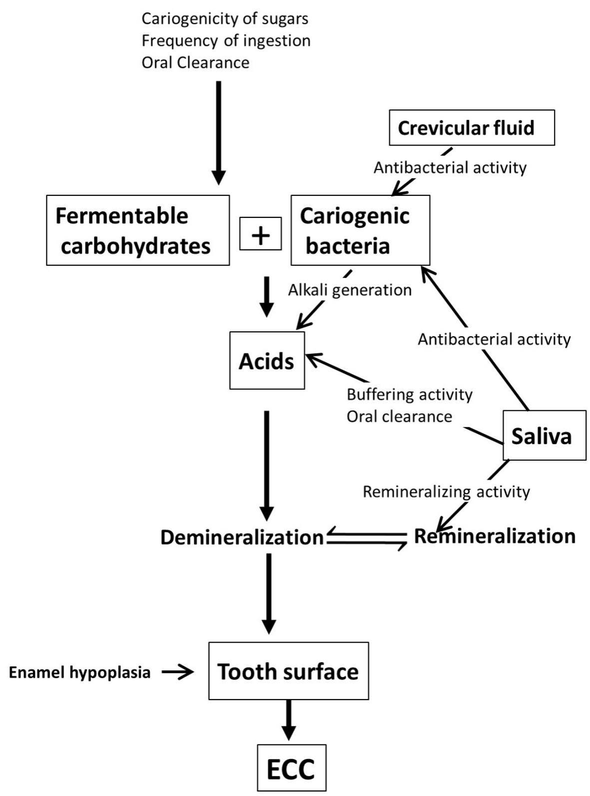
Figure 2.1 Caries balance and the determinants of early childhood caries



2.3.1 Primary Pathology

The primary interaction pathway for ECC occurs between cariogenic bacteria in the mouth and fermentable carbohydrate over time (Figure 2.1). Specifically, caries balance is shifted towards demineralisation via prolonged periods of oral dysbiosis in the presence of free sugars (Featherstone, 2008; Kilian et al., 2016). This interaction is depicted in Figure 2.2, reproduced from Seow (1998).

Figure 2.2 Brief overview of the caries process



Reproduced from Seow (1998). Used with permission (Appendix A).

Dysbiosis occurs when cariogenic bacteria multiply to substantially higher levels than normally present in the mouth (Kilian et al., 2016). This is driven by a supportive oral environment, where available carbohydrates are fermented in the mouth, lowering the pH around the tooth surfaces. Acidophilic (acid-loving) and acidogenic (acid-producing) bacteria, primarily *Streptococcus mutans*, but also *Streptococcus sobrinus* and some *Lactobacilli* flourish under these conditions, aggregating on the surface of the tooth to form a biofilm, which causes acid levels to further increase, promoting demineralisation of tooth enamel (Colak et al., 2013; Hinds et al., 2016; Kilian et al., 2016). Prolonged periods of demineralisation shift the caries balance towards disease, therefore the amount of available carbohydrate and the frequency and duration of exposures are critical regulators of caries balance (Kilian et al., 2016). The oral microbiome is dynamic, influenced by a wide range of factors coming from both host and microbial processes, which are in turn modified by the external environment (Kilian et al., 2016).

Not all carbohydrates are freely available in the mouth for fermentation by cariogenic bacteria. Those that are available are collectively referred to as 'free sugars'. According to the World Health Organization,

> "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."
>
> (World Health Organization, 2015, p. 5)

Diets high in free sugars are associated with increased tooth decay and higher body weight (WHO, 2015). Sources of free sugars tend to be energy-dense, nutrient-poor, non-core foods and drinks, which are consistently implicated in chronic disease development (NHMRC, 2013). There is no consistent evidence linking non-free sugars (those that are naturally present within the structure of intact fruit and vegetables and in milk products) with adverse health outcomes (WHO, 2015).

Despite the transmissible nature of cariogenic bacteria, dental caries is considered a non-communicable disease, as the bacteria do not independently cause caries but act in response to free sugars exposure (Tinanoff et al., 2019). *S.mutans* is present in the mouth at low levels across all populations, and does not multiply to cariogenic levels unless in the presence of free sugars (Sheiham & James, 2015). Sugar is the most important dietary factor in the development of dental caries (Moynihan & Kelly, 2014; Sheiham & James, 2015; WHO, 2003a), and caries prevalence around the world reflects population-level differences in the amount and frequency of free sugars exposure (Moynihan & Petersen, 2004; Sheiham & James, 2015). The dose-response relationship between free sugars intake and dental caries has been observed in a range of population settings and contexts, collectively demonstrable in reviews and meta-analyses (Moynihan & Kelly, 2014; Sheiham & James, 2014). It is the frequency and amount of free sugars in the mouth that supports the proliferation of cariogenic bacteria, leading to dysbiosis and a negative shift in caries balance towards demineralisation (Sheiham & James, 2015; Tinanoff et al., 2019).

In light of this, there are calls for a stronger focus on this primary interaction pathway in research and practice (Sheiham & James, 2015). At the same time, with an increased understanding of upstream determinants in population health, others argue for a broader perspective (Fisher-Owens et al., 2007; Phantumvanit et al., 2018). This seemingly straightforward interaction between sugars and cariogenic bacteria becomes much more complex when the wide range of determinants are considered.

2.3.2 Proximal Determinants

Proximal determinants directly impact the primary interaction pathway. In the case of ECC, these are factors which disrupt caries balance, by moderating the frequency and amount of exposure to free sugars or the proliferation of cariogenic bacteria on the tooth surface; or by buffering the demineralisation and remineralisation process (Figure 2.1, p. 16). Fluoride, calcium and phosphorous contribute to this buffering effect; therefore dietary intakes are relevant to caries balance beyond their provision of free sugars (Moynihan & Petersen, 2004). Oral health practices can assist with the application of fluoride to the tooth surfaces and the mechanical removal of plaque to disrupt dysbiosis (Phantumvanit et al., 2018). The establishment of the oral microbiome in early life is a critical window of opportunity for caries prevention, and can be influenced by oral health and hygiene practices of the primary caregivers (Kilian et al., 2016).

2.3.2.1 Fluoride Exposure

Fluoride has several mechanisms of action in ECC prevention. During demineralisation, fluoride ions act on the tooth enamel as a buffer, slowing the rate of carbohydrate metabolism by bacteria and reducing the severity of degradation (Featherstone, 2008; Moynihan & Petersen, 2004). Fluoride also speeds up remineralisation by attracting calcium ions to the tooth surface, which then attract phosphate ions and start to rebuild the affected area (Featherstone, 2008). Additionally, when fluoride is present during remineralisation, lesions uptake fluoroapatite rather than hydroxylapatite, rendering them less susceptible to future attacks (Blinkhorn & Mekertichian, 2013; Moynihan & Petersen, 2004). The use of fluoride-containing toothpaste is a key source of oral fluoride exposure for caries prevention (dos Santos et al., 2013; Phantumvanit et al., 2018), however as an individual health behaviour, compliance is influenced by a wide range of distal determinants (see 2.3.2.3 Oral Health Practices and 2.3.3 Distal Determinants).

Many nations add fluoride to the mains water supply as a public health strategy. In Australia, water fluoridation is managed independently by each state and territory (NHMRC, 2017b). Around 89% of Australians currently live in areas where fluoride is added to the water, to levels ranging from 0.6 to 1.1 mg/L, in line with recommendations (NHMRC, 2017c). A recent review concluded that the current approach to public water fluoridation is appropriate and effective at reducing caries presence and severity throughout the life course (NHMRC, 2017b). Public water fluoridation diminishes some of the social inequality in caries experience (NHMRC, 2017b). With the exception of differences between people living in urban and rural areas, access to a fluoridated public water supply does not differ by socio-economic position, nor does it require financial resources or individual health behaviours (NHMRC, 2017b).

Water is the primary source of ingested fluoride in Australia, via fluoridated mains water and the consumption of foods and beverages prepared using this water (Cressey et al., 2009; FSANZ, 2009). Grains including rice, pasta, quinoa, millet, wheat and related products such as bread, are some of the highest solid food sources of fluoride in Australia due to the large water uptake relative to weight during cooking (FSANZ, 2011a). During early childhood, infant formula that has been prepared using fluoridated water is a key source, although the formula powder itself is generally low in fluoride (Australian Government, 2017a; FSANZ, 2011a). Sources other than fluoridated water include tea leaves, fish, ice-cream and cheese; and there is some uptake by plants grown with a fluoridated water supply or sprayed with fluoride-containing fertilisers and pesticides (Cressey et al., 2009; FSANZ, 2011a).

Despite clear evidence that fluoride reduces dental caries prevalence, it is not solely able to eliminate caries, particularly in the presence of moderate-to-high free sugars consumption (Sheiham & James, 2015; WHO, 2015). Well-fluoridated populations still experience dental caries, with most disease expressed in adulthood, and prevalence increasing with age (AIHW, 2019; WHO, 2015). Evidence reviews estimate that water fluoridation reduces caries prevalence by around 26-44% in children, teenagers and adults (NHMRC, 2017b). A meta-analysis found that topical fluoride applications (including gels, varnishes and toothpaste, but excluding water) were associated with a 33% reduction (95% CI, 22-44%) in dental caries in the primary dentition (Marinho et al., 2003). Water fluoridation is, therefore, an effect modifier in caries research, potentially delaying onset of caries when compared to non-fluoridated populations (Moynihan & Kelly, 2014; Sheiham & James, 2015).

2.3.2.2 Dietary Factors

The World Health Organization (2015) recommends that intakes of free sugars in adults and children should contribute less than 10% of total energy intake, with a conditional recommendation (based on lower-quality evidence) to further reduce free sugars to less than 5% of energy intake. They also recommend no addition of sugars to complementary foods in the first 2 years of life (WHO, 2017c). The Australian Infant Feeding Guidelines make similar recommendations, stating that complementary foods "…should be of acceptable taste without added sugar, honey or salt" (NHMRC, 2012a, p. v). Similarly, the Australian Dietary Guidelines, last reviewed before the WHO (2015) sugars guideline was released, advise consumers to "limit intake of foods containing saturated fat, added salt, added sugars and alcohol" (NHMRC, 2013, p. 5).

Free sugars are not analytically discernible from other sugars, as the definition relates to food source and health outcomes, rather than chemical composition (WHO, 2015). Diets that are lower in free sugars tend to align with population healthy diet recommendations for chronic disease prevention, with minor exceptions. For example, Australians are encouraged to enjoy a wide variety of nutritious core foods, including fruits, vegetables, legumes, whole grain cereals, eggs, nuts and seeds, with moderate amounts of milk products, lean meat and their alternatives; and to limit intake of energy-dense, nutrient-poor foods and drinks (NHMRC, 2013). For the most part, these foods are low in free sugars. The consumption of dried fruit and fruit juices may be interpreted differently when prioritising oral health versus nutrient intake, as these foods are both nutrient dense and cariogenic. With this in mind, the Australian Dietary Guidelines (NHMRC, 2013) classify any juices that are less than 100% fruit as non-core discretionary foods, similar to sugar-sweetened beverages.

Dried fruit and 100% fruit juices are included with whole fruit in lists of core foods, but the Guidelines recommend selecting those with no added sugar and using them occasionally, as a substitute for other fruit sources in this group (NHMRC, 2013).

In Australia, compliance with these recommendations is generally poor, with energy-dense, nutrient-poor foods and drinks contributing around 39% of daily energy intake among children aged from 2 to 18 years; and 35% of energy intake among adults 19 years and older (ABS, 2015). Free sugars contribute around 13% and 10% of daily energy intake for children and adults, respectively. In addition, the median number of serves from each of the core food groups fall below the recommendations across all age groups (ABS, 2015). There are no Australian national dietary intake data for children under 2 years of age, however findings from cohort studies indicate that compliance with dietary guidelines is similarly poor (Atkins et al., 2016; Bell et al., 2016a; Byrne et al., 2014; Koh et al., 2010; Lioret et al., 2013; Spence et al., 2018). No Australian cohort studies to date report free sugars intakes in the first 2 years of life.

Beyond the dose-response relationship between free sugars intakes and dental caries, the effects of frequency and timing of free sugars exposure on caries risk are less clear. The mechanism of action is plausible, given exposure time is a key factor in the primary pathway (Feldens et al., 2018; Tinanoff et al., 2019). Frequent consumption of foods and beverages high in free sugars has been implicated in shifting caries balance towards demineralisation, particularly when consumed as between-meal snacks (Harris et al., 2004; WHO, 2017c). Practice guidelines often recommend reducing the total number of exposures to free sugars, only consuming sweetened drinks at mealtimes and not giving children sweetened drinks at bed time (Baghlaf et al., 2018; WHO, 2017c).

A recent meta-analysis investigated whether exposure to free sugars at bed time is an independent risk factor for dental caries in children (Baghlaf et al., 2018). If free sugars are present during the night, caries balance may be shifted towards demineralisation to a greater extent than during the day, due to the reduced salivary flow during sleep (Nakayama & Mori, 2015; Weber-Gasparoni et al., 2007). Although the included studies showed consistent, positive associations between bed time exposure to free sugars and dental caries, it is difficult to draw conclusions as the studies involved were rated as “very low” methodological quality (Baghlaf et al., 2018). Very few studies controlled for daily intake of total or free sugars, and around half investigated tooth brushing practices after the bed time feed. The most consistent evidence of association was among pre-school aged children, with all 7 included studies showing a positive association between higher frequency of exposure to free sugars at bed time and increased dental caries (Baghlaf et al., 2018).

In addition to free sugars, other dietary factors have been linked to caries balance, both towards demineralisation (undernutrition), and remineralisation (calcium, phosphorous and foods that stimulate saliva production). Though the strength of evidence of an association varies, these factors all have plausible mechanisms of action relating to the primary interaction pathway (Moynihan & Petersen, 2004).

The effect of free sugars on caries prevalence is heightened in the presence of undernutrition (Moynihan & Petersen, 2004). Protein-energy malnutrition and vitamin A deficiency are associated with enamel hypoplasia and salivary gland atrophy, both of which contribute negatively to caries balance in the presence of free sugars (Moynihan & Petersen, 2004). It is likely that there are other mechanisms by which undernutrition contributes to increased caries risk which remain unknown.

Calcium and phosphate ions are lost from the surface of the tooth during demineralisation, and returned during remineralisation to rebuild the surface structure with the assistance of fluoride (Featherstone, 2008). Saliva is a key source of calcium and phosphate ions both in preventing demineralisation and providing substrates for remineralisation, but dietary calcium and phosphorous may also assist in this process (Adegboye et al., 2017; Featherstone, 2008). Milk products are high in calcium and phosphorous and usually do not contain free sugars (NHMRC, 2013), so are likely to be carioprotective. Hard cheeses increase plaque calcium concentration, stimulate saliva production and are granted a probable association with decreased caries prevalence (Moynihan & Petersen, 2004).

Saliva is a critical mediator of caries balance, by regulating the oral microbiome, buffering oral pH and providing a high saturation of calcium and phosphate ions at the tooth surface (Featherstone, 2008; Kilian et al., 2016). For these reasons, it has been suggested that foods that stimulate saliva production may reduce caries prevalence (Phantumvanit et al., 2018; WHO, 2003a). The evidence for sugar-free chewing gum in this role is established (Keukenmeester et al., 2013; Mickenautsch et al., 2007). Other foods that have been proposed as potentially beneficial include whole grain and fibrous foods, nuts and hard cheeses (Lingström & Moynihan, 2003; WHO, 2003a), though research into any of these is sparse.

It may be that each of the dietary factors discussed above have negligible impacts on caries risk in isolation, but when combined into an overall dietary pattern, a greater effect may be observed. Few studies to date have employed dietary pattern analysis methods to investigate ECC, but those that have done so consistently observe lower ECC experience among participants with higher diet quality scores (Chaffee et al., 2015; Hu et al., 2019; Nunn et al., 2009). A healthy dietary pattern may be particularly important in early childhood, as foods consumed early in life can set children up with dietary preferences and behaviours that continue through childhood and beyond (Craigie et al., 2011; Nicklaus, 2009; Scott et al., 2012). Dietary behaviours are affected by a range of distal determinants, discussed in 2.3.3 (p. 26).

2.3.2.3 Oral Health Practices

Recommended oral health practices include twice-daily tooth brushing and flossing, and regular visits to a dentist, commencing in early childhood (Australian Dental Association [ADA], 2018b; Phantumvanit et al., 2018; WHO, 2017c). Tooth brushing and flossing help to shift caries balance toward remineralisation by the mechanical removal of plaque and the topical application of fluoride. Excessive plaque accumulation promotes dysbiosis, so manual removal minimises the areas where cariogenic bacteria can accumulate (Kilian et al., 2016). Tooth brushing should commence with the eruption of the first tooth, using an infant toothbrush or parent's finger covered with a soft cloth (Manton & Hayes-Cameron, 2013). Parents should continue to supervise child tooth brushing up to at least 7 or 8 years of age, to reduce both fluorosis and caries risk (Blinkhorn & Mekertichian, 2013). Twice-daily supervised tooth brushing throughout early childhood will help children to adopt these habits in the long-term (ADA, 2018b; Manton & Hayes-Cameron, 2013).

Recommendations regarding the use of fluoridated toothpastes in early childhood vary from country to country, due to variations in water fluoridation initiatives and considerations of fluorosis prevention (Manton & Hayes-Cameron, 2013; Phantumvanit et al., 2018). In Australia, low-fluoride toothpastes (containing between 400–550 ppm fluoride) are recommended for children from 18 months to 6 years of age who are living in fluoridated areas, with studies showing lower rates of fluorosis among children who used these than children using the family toothpaste (containing greater than or equal to 1000 ppm fluoride) (ADA, 2018b; Spencer & Do, 2008). Low-fluoride toothpastes are not recommended in areas without fluoridated mains water due to insufficient caries prevention (Blinkhorn & Mekertichian, 2013). The amount of toothpaste placed on a child's brush should be minimal, with a 'smear' or 'rice-sized' amount for children under 3 years of age, and then a 'pea-sized' amount for children from 3 to 6 years (Blinkhorn & Mekertichian, 2013; Phantumvanit et al., 2018; WHO, 2017c).

Dental visits are also encouraged in early childhood, as an opportunity for education and early intervention, as well as the normalisation and habit-forming nature of annual checks. The first dental visit should occur within the first year of life, no more than 6 months after the first tooth erupts (ADA, 2018b; Tinanoff et al., 2019). The Australian Government provides funding for basic dental services for children aged from 2 to 17 years via the means-tested Child Dental Benefits Schedule, however uptake is currently low, with around 30% of eligible children accessing the program in 2014–15 (Commonwealth of Australia, 2015). In addition, the program does not include children younger than 2 years of age, requiring parents to self-fund or utilise private health insurance for initial dental visits; strategies which are only available to families with higher socio-economic position (see 2.3.3.1). In the Australian National Child Oral Health Study, only 57% of children had visited the dentist before the age of 5, with lower rates among children from socio-economically disadvantaged backgrounds (46% of children from low-income households, and 45% of children of parents who had school-only education) (Do & Spencer, 2016).

2.3.2.4 Establishment of the Oral Microbiome

The oral microbiome is one of the most diverse in the body, second only to the overall gastrointestinal tract (Kilian et al., 2016). Early exposure to *S.mutans* has been linked to increased caries risk (American Academy of Pediatrics, 2014; Manton & Hayes-Cameron, 2013). The oral microbiome is established in early childhood, with some evidence that the greatest influence occurs between 6 months and 2 years of age, coined the "window of infectivity" for cariogenic bacteria to colonise (Caufield et al., 1993). As observed in the rest of the gastrointestinal tract, the oral microbiome of children who are vaginally delivered, and those who are breastfed differs from those born via caesarean section and those who are formula fed (Holgerson et al., 2013; Kilian et al., 2016). This may partially explain why a recent cohort study found that children born by caesarean section had a higher risk of ECC at 5 years than those delivered vaginally (Boustedt et al., 2018). A healthy oral microbiome promotes good caries balance by competing with cariogenic bacteria for proliferation, reducing dysbiosis (Kilian et al., 2016).

Additionally, colonisation by *S.mutans* is amplified via vertical transmission of bacteria from the mouths of primary caregivers (da Silva Bastos et al., 2015; Kilian et al., 2016). Children with greater *S.mutans* concentrations tend to have mothers with poorer oral health than those with lower concentrations (Seow, 2012). Interventions to reduce maternal *S.mutans* concentration have been shown to delay colonisation of the infant oral microbiome by several months (Leong et al., 2013). Some exposure is inevitable, however it is intensified when parents share utensils with children, pre-chew their food, or suck the dummy with the intent to clean it prior to placing it in the child's mouth (Colak et al., 2013; Fisher-Owens et al., 2007). The dental health of primary caregivers also influences the caries experience of the child through more distal factors such as behavioural role-modelling and support (Skeie et al., 2006; Tinanoff et al., 2019) (see 2.3.3.2).

2.3.3 Distal Determinants

The effects of distal determinants are more indirect, occur higher up in the causal pathway and are often interrelated, compounding the effect of determinants closer to the primary pathway (Figure 2.1, p. 16). Socio-economic position and family level influences manifest primarily at the household level, while public health policy and practices operate even further upstream. These factors may act on caries balance directly, or affect the proximal determinants which, in turn, influence caries balance.

2.3.3.1 Socio-Economic Position

Socio-economic position is linked to a range of health inequalities, many of which appear to be widening in economically developed countries (Swinburn et al., 2019; WHO, 2011). There is a significant disparity of caries experience in Australia, with 50% of children from low income households experiencing dental caries, compared to 33% of children from high income households (Do & Spencer, 2016).

The mechanisms by which socio-economic advantage results in better oral health outcomes are not fully known, however socio-economic position is indicated by education, income and occupation, which have each been linked to health literacy and compliance with a range of health behaviours and health outcomes (AIHW, 2018; Schwendicke et al., 2015; Seow, 2012). This social gradient is observed in the oral health practices of Australian children. The Australian National Child Oral Health Study reported that children with greater socio-economic disadvantage were less likely to visit a dentist before their fifth birthday, conform to a regular dental visiting pattern, commence fluoride toothpaste use between 18 and 30 months of age, and brush their teeth twice a day than those with greater socio-economic advantage (Do & Spencer, 2016).

Cost is a notable barrier to accessibility of dental services in Australia, with 41% of people in the lowest quintile of household income reporting avoiding or delaying a visit to the dentist due to cost; far more than those in the highest quintile (17%) (AIHW, 2019). Similarly, 44% of those without private health insurance, but only 20% of those with insurance, reported avoiding or delaying a dental visit (AIHW, 2019). The Australian Government private health insurance rebate and lifetime health cover loading provide financial incentives to maintain private health insurance (AIHW, 2018), however the premium costs are still prohibitively high for many people on lower incomes (ABS, 2017b). People living in the most socio-economically advantaged areas had the highest rates of private health insurance (79%), while the lowest rates (34%) were seen among people living in the most disadvantaged areas (ABS, 2017b).

Socio-economic position also affects diet quality, with higher scores on healthy eating indices and other dietary pattern measures observed in populations experiencing greater socio-economic advantage (Darmon & Drewnowski, 2008; Olstad et al., 2018). A social gradient for diet quality has been observed cross-sectionally among Australian children aged from 2 to 18 years in the National Nutrition and Physical Activity Survey (Cameron et al., 2012), tracked from birth over a period of 5 years in the Infant Feeding Activity and Nutrition Trial (Spence et al., 2018), and over 10 years in the Longitudinal Study of Australian Children (Chung et al., 2018). Parental education is a consistent indicator of this gradient, which may reflect correlations between education and health literacy, self-efficacy and the ability to translate nutrition knowledge into action (Berkman et al., 2011; Commonwealth of Australia, 2014; Lacy et al., 2019; Zarnowiecki et al., 2014).

This disparity may also be due to the availability and accessibility of healthy foods within the home, with community and household food security a contributing factor to diet quality (Olstad et al., 2018; Zarnowiecki et al., 2014). Although national data reports that around 4% of households are food insecure (ABS, 2014a), the data is generated from a single-item question, and more comprehensive measures employed in non-representative samples suggest the number of food insecure households may be much higher (Butcher et al., 2019; McKechnie et al., 2018). The rates of food insecurity are substantially higher among population sub-groups who experience disadvantage and/or marginalisation (ABS, 2014a; Butcher et al., 2019; Pollard et al., 2015a; Ramsey et al., 2011). Modelling studies demonstrate the lack of affordability of basic healthy food for low-income and welfare-dependent families in Australia (Kettings et al., 2009; Pollard et al., 2015b; Ward et al., 2013). Many parents experiencing low-income identify food as a limited household resource and perceive healthy food as more expensive than unhealthy food, reporting cost to be a major driver of purchasing decisions (Daniel, 2016; Petrunoff et al., 2014).

There are many other considerations in this disparity in diet quality by socio-economic position, including differences in the symbolic value of food (Fielding-Singh, 2017b). For low-income parents who make all decisions under a framework of economic scarcity, food provision can be a rare opportunity to acquiesce to their child's requests (Fielding-Singh, 2017b). This can then be a low-cost way for parents to feel a sense of parenting competence, being able to express love and care by meeting an expressed desire of the child (Fielding-Singh, 2017b). For higher-income families, food fulfils different ideals of parenting competence and provides a setting in which to demonstrate parenting success to others. Many parents who experience high incomes see food provision as an opportunity to instil values around restraint, delayed gratification and self-control in their child, while cultivating a penchant for healthy foods (Fielding-Singh, 2017b). These differing valuations of food result in contradictory responses when a child makes a request for unhealthy food, but both come from an intention to parent competently.

2.3.3.2 Family-Level Influences

Beyond socio-economic position, family structure and function influences dental, dietary and general health behaviours and health outcomes. Correlations have been established between maternal and child caries experience, along with some determinants such as sugar consumption and oral population of *S.mutans* (Seow, 2012). Family composition, cohesion, role modelling and support have direct and indirect influences on dietary and oral health behaviours (Fielding-Singh, 2017a; Fisher-Owens et al., 2007; Pearson et al., 2009). The health status of parents, and their modelled attitudes and behaviours toward dental and other health professionals shape the attitudes and behaviours of children (Fisher-Owens et al., 2007). Although the evidence is still forthcoming, it is postulated that health beliefs, locus of control and self-efficacy all play a role in shaping parental knowledge, attitudes, and behaviours around dental caries, which are then passed on to children (Seow, 2012; Tinanoff et al., 2019). Many of these factors are interrelated, and differ between cultural and ethnic groups and across socio-economic bands, which may partially explain the disparity in caries experience along a socio-economic gradient.

The early years of motherhood can be a challenging time, during which maternal identity is formed and ideologies around ‘good mothering’ can be both drivers of, and barriers to, healthy behaviours (Harrison et al., 2018; Lupton, 2011). This life stage is full of teachable moments; when motivations, opportunities and capabilities change and the uptake of new healthy behaviours may be achieved (Olander et al., 2016; Phelan, 2010). For many mothers, motivation to mitigate risks to which their child might be exposed is high (Lupton, 2011). The decision-making processes around health behaviours occur within a network of socially constructed norms and values that may align with, or undermine, evidence-based guidelines (Begley et al., 2019; Lupton, 2011; Matvienko-Sikar et al., 2018).

The family environment in early childhood plays a key role in establishing oral health care behaviours, including twice-daily tooth brushing and flossing and regular dental visits (Phantumvanit et al., 2018). These are promoted via sibling and parental modelling, support and encouragement for the child to undertake these behaviours (Fisher-Owens et al., 2007; Phantumvanit et al., 2018; Seow, 2012). Maternal attitudes towards, and confidence in their oral health behaviours are associated with child oral health status (Seow, 2012). Dental anxiety and fear of pain with dental treatment expressed by parents may be passed on to children directly, or may result in modelling the avoidance of, or infrequent access to, dental services (Fisher-Owens et al., 2007).

Family structure and function also influence the household food environment, which determines diet quality in early childhood and beyond (Zarnowiecki et al., 2014). Parents have substantial control over what foods are available in the house and presented at mealtimes, however these foods reflect the family dynamic, negotiations and extent of compromise and influence by all family members (Fielding-Singh, 2017a; Martin-Biggers et al., 2018). Consequently, a child's food exposures from household availability are shaped by the food preferences of parents and siblings (Daniel, 2016; Fielding-Singh, 2017a). In many households, women continue to do the majority of unpaid household work, regardless of employment status (ABS, 2016a). A recent study from the United States of America (US) found that while mothers were the primary food provider, most fathers assumed either a passive or even obstructive role in the provision of healthy food to children (Fielding-Singh, 2017a).

Parents also set the household rules around eating, and enforce them via modelled eating behaviours and parenting style, particularly during the evening meal (Collins et al., 2016; Daniel, 2016; Litterbach et al., 2017; Zarnowiecki et al., 2014). In a survey of Australian parents of children aged from 0 to 6 years (n = 992), 77% of families reported eating dinner together with the child or children and at least one parent, at least five nights per week (Litterbach et al., 2017). This appears to continue beyond childhood, with a survey of adolescents approximately 15 years of age reporting that 70% participated in what they identified as a family meal the previous night (survey $n = 625$) (Gallegos et al., 2011). Higher frequencies of shared family meals are associated with healthier eating patterns, greater likelihood of being in the healthy weight range, and less disordered eating behaviours among children and adolescents (Hammons & Fiese, 2011).

Single-parent families experience a unique dynamic of eating behaviour, with higher rates of food insecurity and poverty in single than couple households (Pollard et al., 2015b). Adolescents in single-parent households reported placing a lower value on the family mealtime than their peers living in couple households (Gallegos et al., 2011). Cross-sectional analysis from the Longitudinal Study of Australian Children observed a number of diet quality indicators were poorer in children from single-parent households (Byrne et al., 2011). The analysis also found higher body mass index among girls from single-parent households but not boys (Byrne et al., 2011); a finding replicated in secondary analysis of two state-wide child health surveys conducted in Queensland (Miura et al., 2017).

From pregnancy onwards, the maternal diet is an important factor in establishing healthy diet patterns, with a wide variety of flavours transmitted from mother to child through amniotic fluid and breast milk (Mennella, 2014). This may increase a child's willingness to try new foods during weaning; particularly if complementary foods reflect the maternal diet during pregnancy and breastfeeding, and if breast milk is used in the preparation of infant foods (Mennella, 2014).

Maternal self-efficacy can be a key driver of healthy dietary behaviours. Children are predisposed to prefer sweet and avoid bitter flavours (Mennella, 2014), so parents need to take an active approach to establishing dietary patterns high in core foods and low in free sugars, including tap water as the main drink (NHMRC, 2013). An Australian study found that greater maternal self-efficacy surrounding the ability to influence their child's diet and physical activity was correlated with healthier behaviours in the 1 or 5 year-old children (Campbell et al., 2010). The study also found that self-efficacy scores were lower among mothers of 5 year-olds than mothers of 1 year-olds. Another Australian study found that self-efficacy among mothers was associated with greater variety of vegetables but not fruit consumed by children at around 6 months of age (Koh et al., 2014).

Pregnancy and the early years of childhood are an ideal time for parental nutrition education and support, however nutrition information is seen by many new parents as challenging and confusing (Begley et al., 2019). During this time, parents actively seek information from a variety of sources including health professionals, friends, family, and the internet (Laws et al., 2019; Matvienko-Sikar et al., 2018; Russell et al., 2016; Spence et al., 2016; Walsh et al., 2015). Food marketing and media create further 'noise', with the promotion of infant formula and foods that undermine parental confidence in complementary feeding practices (Harrison et al., 2017; Walsh et al., 2015; WHO, 2017a). Parents report struggling with 'information overload' as they learn the activities of child-rearing and adjust to their new roles (Loudon et al., 2016; Matvienko-Sikar et al., 2018). Nutrition misinformation may have a significant influence on infant feeding decisions as parents navigate the challenges of translating information into health actions, and balancing conflicting advice.

In early childhood, the family food environment supports the establishment of food norms, with higher diet quality seen among children who were breastfed rather than formula fed (Grieger et al., 2011; Scott et al., 2012), and given repeated exposures of a wide variety of complementary foods in the second 6 months of life (Drewnowski et al., 2012; Mennella, 2014; Nicklaus, 2009). This is particularly challenging for families with greater socio-economic disadvantage, due to the costs associated with food waste (Daniel, 2016). Some parents experiencing low income and/or food insecurity minimise food waste by limiting a child's agency over food rejection, however many undertake more conciliatory strategies such as only selecting foods they know their child will like, avoiding experimentation or repeated introduction of initially disliked foods, and only introducing new foods if they are already liked by other members of the household (Daniel, 2016). These strategies limit the opportunities for children in low-income families to acquire a taste for a wide variety of nutritious foods.

Many of these factors are affected by family functioning (Martin-Biggers et al., 2018). Home environments with high levels of conflict and chaos and low cohesion have been associated with unhealthy food behaviours among children aged from 2 to 5 years and their mothers, even after controlling for key socio-demographic factors (Martin-Biggers et al., 2018). Households experiencing food insecurity are also more likely to be disrupted by chaotic living conditions, residential crowding and a lack of structure in many areas, including less mealtime planning and inconsistent eating routines (Fiese et al., 2016). The determinants described above are likely to disproportionately affect households with low socio-economic position, compounding the effect of these inter-related determinants.

2.3.3.3 Public Health Actions

The determinants of ECC are influenced by the state of public health in Australia. Government policies surrounding mains water fluoridation schemes, public dental services, financial incentives for private health insurance, oral health promotion and population monitoring and surveillance all contribute to caries-related oral health behaviours (COAG Health Council, 2015; Phantumvanit et al., 2018). Australia's National Oral Health Plan 2015-2025 provides a framework for action, building on the gains that have occurred via the first National Oral Health Plan 2004-13 (COAG Health Council, 2015). This progress resulted in oral health action being named 1 of the top 10 public health successes over the last 20 years (PHAA, 2018e). In particular, improvements in public water fluoridation and the implementation of the Australian National Child Dental Benefits Schedule were identified as key actions during this period (PHAA, 2018e).

Public health efforts around food and nutrition have been less forthcoming, reflecting a lack of government policy in this area. Translation of evidence into action has stalled in Australia and globally (Swinburn et al., 2019), with the last national nutrition policy in Australia published in 1992 (PHAA, 2018b). Australian diet quality is affected by the lack of public health initiatives to create healthy food environments, despite clear recommendations for government action (Vandevijvere & Swinburn, 2017). Some of these relate directly to free sugars, such as a sugar-sweetened beverages tax (Backholer et al., 2016a; Lal et al., 2017), improved front-of-pack labelling (Jones et al., 2018; Moore et al., 2019; PHAA, 2017b), and the addition of added sugars to nutrition information panels (PHAA, Food Regulation Standing Committee, 2019; 2018d). Other recommendations target broader diet quality outcomes, including restricting the promotion of unhealthy food and drinks to children (Sacks et al., 2019; WHO, 2016), creating healthier food environments in child-care settings, schools and sporting clubs (WHO, 2016), subsidising the cost of healthy foods to vulnerable populations (Friel et al., 2015), reformulation of the food supply (Sacks et al., 2019), and improved regulation to restrict the marketing of breast milk substitutes (COAG Health Council, 2019; WHO, 1981; WHO, 2019b). The lack of action globally is attributed to policy inertia, described as

> "the combined effects of inadequate political leadership and governance to enact policies…, strong opposition to those policies by powerful commercial interests, and a lack of demand for policy action by the public."
>
> (Swinburn et al., 2019, p. 791).

These strategies are further discussed in Chapter 6 (see 6.5 *Recommendations for Public Health Action*, p. 209).

2.4 Do Breastfeeding Practices Contribute to ECC Risk?

There is a clinical consensus within sectors of the dental workforce that breastfeeding is a risk factor for ECC (Arora et al., 2011; Colak et al., 2013). The association was first reported via case studies of nine children in 1977 (Kotlow, 1977) and has been inconsistently observed ever since. In high-income countries, breastfeeding is associated with higher socio-economic position, and may serve as a proxy indicator for a range of other healthy behaviours, leading to positive associations in studies that have not sufficiently controlled for covariates. In low- and middle-income countries, from where much of the research into this hypothesis originates, clustering with unhealthy behaviours may be leading to negative associations. Nevertheless, the mechanisms of action of breastfeeding on ECC risk are plausible but inconsistent, with breastfeeding practices demonstrating both cariogenic and carioprotective characteristics (see 2.4.1).

Until recently, findings from the evidence base have been inconsistent and conclusions elusive. A systematic review published in 2000 (Valaitis et al.) observed a myriad of inconsistencies and problems with research methods, and provided clear recommendations for future studies to follow. Research since then has begun to address some of the methodological limitations reported by Valaitis et al. (2000), and three recent, systematic reviews report tentative, but consistent findings, with greater homogeneity found between studies of higher quality (see 2.4.2). These reviews suggest that there is more nuance to the possible association between breastfeeding and ECC than first thought.

2.4.1 Plausible Mechanism

In vitro and animal studies indicate that human breast milk has a less cariogenic effect on teeth than infant formula (Aly et al., 2019; Peres et al., 2009), however the difference is reduced substantially when the formula is reconstituted with fluoridated water (Peres et al., 2009). Comparisons to unsweetened cow's milk have found breast milk to be slightly more cariogenic in de-salivated rats (Peres et al., 2009), but with similar cariogenicity in the presence of saliva in a microcosm biofilm model (Signori et al., 2018). One study found that, in the absence of saliva, breast milk promoted lesser growth of *S.mutans* than unsweetened cow's milk, but also had lower pH buffering capacity (Prabhakar et al., 2010), supporting the hypothesis that breast milk has both carioprotective and cariogenic properties relative to cow's milk. However, *in vitro* studies do not consider the full range of influences on caries balance and serve only as a starting point.

The potential mechanisms by which breastfeeding may shift caries balance in either direction relate to the nutrient composition and non-nutritive properties of breast milk itself, behavioural patterns associated with the act of breastfeeding, and what the alternatives are over the first 2 years of life.

2.4.1.1 Nutrient Composition

The current definition of free sugars does not mention human breast milk, however it is assumed that, like other animal milks, human milk does not contain free sugars. Table 2.1 compares the nutrient composition of human, animal and plant-based milk products including infant formula, for sugars, calcium, phosphorous and fluoride. Compared to cow's milk and soy milk, human breast milk is higher in total sugars and lower in calcium and phosphorous, properties that suggest greater cariogenic potential. However, it appears that soy milk is the only one of these three that contains free sugars.

Table 2.1 Selected nutrient composition of human, animal and plant-based milk products

	Composition per 100g							
	Sugars (g)					Ca	P	Fl
	Total	Lactose	Sucrose	Other	Free	(mg)	(mg)	(μg)
Human breast milk[1]	7.1	7.0[2]	0	HMO-0.5-1.5[2]	0	33	15	1.3[3]
Cow's milk, full fat[1]	6.1	6.1	0	0	0	107	91	4.5[4]
Soy milk[1]	2.7	0	1.3	M-1.3	1.8	118	71	35
Infant formula, cow's milk based, 0-6 months[5]	7.3	ns	ns	ns	0*	50	32	6.4[6]
Infant formula, soy based, all ages[7]	7.2	0	0	G-ns	≤7.2*	87	44	14.5[6]

Ca Calcium, P Phosphorous, Fl Fluoride, HMO Human Milk Oligosaccharides, M Maltose, ns not stated, G Glucose

Data Sources:

[1] Australian Food Composition Database – Version 1 (formerly NUTTAB) (FSANZ, 2019a)
[2] Approximated from a non-systematic review of 7 studies, international sources (Bode, 2012)
[3] Australian and New Zealand Nutrient Reference Values for Fluoride (NHMRC, 2017a)
[4] The 23rd Australian Total Diet Study (FSANZ, 2011a)
[5] Product labels, mean of 4 brands of non-hydrolysed, cow's milk based formula (Karicare, Nan Comfort, S-26 Original, S-26 Gold), viewed 6 September 2019
[6] Analytically derived from Australia formula samples, 0-12 months, reconstituted with non-fluoridated water, (Clifford et al., 2009)
[7] Product label, Karicare Soy, all ages, viewed 6 September 2019
*inferred from other values

Given the lactose intrinsic in cow's milk is not associated with ECC, it is plausible that the lactose intrinsic in human milk is unlikely to be associated with ECC. The type of sugar is not independently cariogenic or carioprotective; although lactose is thought to be the least cariogenic mono- or di-saccharide (Moynihan & Petersen, 2004). Carbohydrate digestion begins in the mouth, so it is plausible that some of the lactose inherent in milk products is available in small amounts for fermentation by cariogenic bacteria. If so, the slightly higher total sugars concentration of human milk may contribute to the difference in cariogenic potential of human and cow's milk that has been observed *in vitro*.

Despite similarities in sugars profile, many other properties of cow's milk and human milk differ, so it may be that the overall food matrix of human milk results in a different caries outcome to cow's milk (Prabhakar et al., 2010). In addition to lactose, human breast milk also contains oligosaccharides not observed in any other foods (Bode, 2012). The role of these human milk oligosaccharides in caries pathology is not yet known.

Plant-based milk alternatives often contain added sugars, as they are naturally low in intrinsic sugars. Soy-based milk alternatives were found to promote a greater rate of acid production and lower buffering capacity than plain cow's milk when exposed to *S.mutans in vitro* (Dashper et al., 2012). An *in situ* crossover trial of teeth placed in intra-oral appliances in human subjects observed demineralisation of teeth exposed to soy milk, but remineralisation of those exposed to unsweetened cow's milk (Shen et al., 2019). Infant and toddler formula made from plant-based sources such as soy also contain free sugars.

Infant and toddler formula vary in their free sugars content. Those based on cow's milk with no additional sugars in the ingredients list are assumed to contain no free sugars. Some cow's milk formula in Australia contains added sugars, usually in the form of added lactose, but also glucose syrup and other sugars. Often these are marketed as partially or fully hydrolysed formula products, but the sugars are added by the manufacturer and therefore classified as free sugars according to the WHO (2015) definition. An *in vitro* study found that sucrose-based formula made from either soy or cow's milk protein isolate (both with added sugars) demonstrated significantly larger increases in biofilm growth than formula made from non-hydrolysed cow's milk, which were all lactose-based (with no added sugars) (Hinds et al., 2016).

The fluoride content of breast milk is low, regardless of whether the mother is consuming fluoridated water. Cow's milk is also low in fluoride, whereas soy milk is higher (FSANZ, 2019a). Infant formula in Australia is generally low in fluoride, regardless of whether it is soy or cow's milk based, to account for reconstitution with fluoridated tap water. The Australia and New Zealand Food Standards Code requires that powdered or concentrated formula containing greater than 17 µg fluoride per 100 kJ prior to reconstitution, or ready-to-drink formula with more than 0.15 mg fluoride per 100 mL, display a warning statement regarding increased risk of fluorosis (Australian Government, 2017a). A 2009 review found no formula in Australia exceeded this value, though the median fluoride concentration in soy formula made up with non-fluoridated water was more than double that of the cow and goat milk formula (Clifford et al., 2009).

2.4.1.2 Non-Nutritive Properties

Human breast milk is a dynamic microbiome, alive with cells, microbes and other bioactive components (Bode et al., 2014; Cacho & Lawrence, 2017). Breast milk has probiotic properties, directly influencing the establishment of the oral and gastrointestinal microbiome (Bode et al., 2014; Holgerson et al., 2013). In contrast, infant formula products must be free from microbial life in order to meet food manufacturing standards, resulting in a reconstituted product that is less microbiologically diverse than breast milk. As a result, children who are breastfed have unique microflora in both the oral and gastrointestinal tract, with notable differences in microbiota from those who are formula fed (Holgerson et al., 2013; Kilian et al., 2016).

Numerous factors in breast milk are thought to inhibit the growth and adhesion of cariogenic bacteria to the tooth. Breast milk contains unique strains of lactobacilli, which have been observed *in vitro* to suppress the growth of *S.mutans* (Holgerson et al., 2013; Wernersson et al., 2006). Human casein and secretory immunoglobulin A from breast milk have also been observed to inhibit the growth and attachment of *S.mutans* to saliva-coated hydroxyapatite models *in vitro* (Danielsson Niemi et al., 2009). Human milk oligosaccharides have been implicated in a wide range of prebiotic and immune mechanisms (Bode, 2012), but to date the effects on ECC have not been investigated.

A randomised crossover trial of children with and without ECC found that breast milk did not decrease the biofilm pH of children in either group, while a sucrose solution did, and to a greater extent among the children with ECC (Neves et al., 2016). These children were all still receiving some breast milk as part of the study inclusion criteria, so selection bias was present, and these results cannot be extrapolated to the non-breastfed population. However, the findings support the hypothesis that breast milk does not act cariogenically in the mouths of children.

2.4.1.3 Behavioural Characteristics of Breastfeeding

Beyond the composition of breast and formula milks, there are also characteristics of breast and formula feeding that have implications for ECC. It is likely that breastfed children follow different patterns of eating and drinking than formula fed children. For example, given the effectiveness of breastfeeding to comfort a distressed infant (Howard et al., 2006), families may give breastfeeds on a more *ad hoc* basis than formula, for reasons beyond feeding. The Australian Infant Feeding Guidelines (NHMRC, 2012a) align with the WHO & UNICEF (2018) recommendation that breastfeeds should be given on demand, in response to the infant’s cues. Breastfeeding promotion messages such as, ‘when in doubt, whip it out!’ (The Milk Meg, 2013) encourage this responsive approach. This increases the frequency of exposure to breast milk, potentially shifting caries balance towards demineralisation.

Breastfeeding is inversely correlated with bottle use, a practice that has been consistently linked to ECC (Feldens et al., 2018; Peres et al., 2018; WHO, 2003a). In Australia, most children who are breastfed receive some expressed breast milk via a bottle (Win et al., 2006) however, in relation to ECC, it is unclear whether bottle feeding with expressed breast milk behaves similarly to breastfeeding or to bottle feeding, or exhibits characteristics of both.

Salivary flow is reduced during sleep, which may be why night-time feeding with any source of free sugars appears to drive demineralisation at a greater rate than day time sugars exposure (Baghlaf et al., 2018; Weber-Gasparoni et al., 2007). If an infant falls asleep while breastfeeding, breast milk may pool in the mouth, increasing the duration of exposure to the teeth (Tham et al., 2015). Routine bed-sharing while breastfeeding, recently named ‘breast-sleeping’, confers a range of benefits (Ball et al., 2019; McKenna & Gettler, 2016), but also increases the frequency of feeding occasions (Gettler & McKenna, 2011), which may promote demineralisation if buffering is insufficient. On the other hand, suckling stimulates salivary flow (Neves et al., 2016), so breast-sleeping may promote greater salivation than a single breast or bottle feed in the night. It may be that breast-sleeping stimulates saliva production at a sufficient rate to buffer the effects of the small but frequent breast milk exposures; though this hypothesis has not yet been investigated.

2.4.1.4 Alternatives to Breast Milk During the First 2 Years of Life

The interactions between breastfeeding and ECC may vary throughout the weaning period. In addition to the establishment of the oral microbiome and the eruption of teeth, a wide range of cariogenic and carioprotective behaviours commence in the first 2 years of life (see 2.3). Dietary patterns are established in early childhood (Amezdroz et al., 2015; Byrne et al., 2014; Byrne et al., 2018; Spence et al., 2018), during which time many habits relevant to ECC risk may be formed. In investigating the mechanisms of breastfeeding as a risk factor for ECC, consideration must be given to the relative cariogenicity of the alternatives to breast milk at various stages in early life.

During the first 6 months of life, the only recommended alternative to breast milk is infant formula (WHO, 2003b, 2019a). Based on the mechanisms described earlier (see 2.4.1), breast milk appears to be less cariogenic than formula, particularly when reconstituted with non-fluoridated water; although this varies by type of formula with differing free sugars content. Breast milk is superior to formula in establishing a healthy microbiome, and confers a range of immunoprotective benefits (see 2.4.1.2). Formula feeding is also associated with early introduction of solid foods (Scott et al., 2009), which is, in turn, associated with the early introduction of energy-dense, nutrient-poor discretionary foods and drinks (Koh et al., 2010), and therefore an earlier potential onset of free sugars intake (WHO, 2017c). Overall, during the first 6 months of life, breastfeeding appears to be the better choice for reducing caries risk than formula. The effects of feeding frequency, breast-sleeping and night-time feeding during this period warrant further investigation, along with comparisons of breastfeeding to formula reconstituted with fluoridated water.

After complementary foods are introduced the comparison is no longer a simple binary between breast milk and formula. The full complement of family foods are at play; which may be accompanied by any combination of breast milk, formula, other animal milks, plant-based milk alternatives, and other sugar-sweetened beverages (Bell et al., 2013; Byrne et al., 2018; NHMRC, 2012a). Children who move from breast milk to fluoridated tap water as their main drink may be at the lowest risk of caries, but those who move on to sugar-sweetened beverages may be at higher risk than if they had continued with breast milk. Cow's milk is not recommended as a drink in the first year of life, though many Australian children drink cow's milk before their first birthday (NHMRC, 2012c). To date, no human studies are available comparing the effects of breast milk to cow's milk on ECC risk in children over 1 year of age (Moynihan et al., 2019).

Overall, there are plausible mechanisms to support the assertion that breastfeeding practices can contribute to ECC risk, particularly once complementary feeding commences. However, plausible mechanisms can only generate hypotheses, and must be confirmed by clinical studies.

2.4.2 Evidence Base

There have been critical, narrative and systematic reviews on the relationship between breastfeeding and ECC, taking a range of approaches and drawing inconsistent conclusions. Some suggest that demand, prolonged and/or night-time breastfeeding may be culpable (Colak et al., 2013; Tham et al., 2015), while others point out that these are not characteristics of breastfeeding *per se*, but rather reflect patterns of feed frequency and timing (Victora et al., 2016). Some reviews acknowledge that the only acceptable alternative to breast milk in the first 6 months of life is infant formula, which has greater cariogenicity than breast milk, and therefore breastfeeding is still the better choice, at least until complementary foods are introduced (Cui et al., 2017; Peres et al., 2018; Tham et al., 2015). They also note that as most studies did not control for all relevant covariates, the evidence is likely to be affected by residual confounding (Avila et al., 2015; Tham et al., 2015). All of these reviews point to the dearth of consistent, high-quality research, and the complexity of investigating this relationship due to the extensive confounding factors and effect modifiers of ECC.

2.4.2.1 Systematic Literature Reviews

Since the narrative review by Valaitis et al. (2000), there have been four systematic reviews investigating breastfeeding and ECC. Avila et al. (2015) focused on only a binary comparison of breastfeeding and bottle feeding, which, coupled with very narrow inclusion criteria, has done little to shed light on the issue. More useful are the reviews by Tham et al. (2015) and Cui et al. (2017), which investigate several exposure windows and breastfeeding practices in their meta-analyses; however the number of included studies that could be pooled was small. Most recently, a review by Moynihan et al. (2019) commissioned by the World Health Organization explores a range of infant feeding practices, including breastfeeding, within a broader investigation of modifiable risk factors for ECC. This review only conducted meta-analyses on 2 out of the 12 review questions, neither of which related to breastfeeding.

Many studies included in these reviews have a relatively weak design, in which breastfeeding exposure is poorly defined and collected retrospectively. It is not possible to establish risk from cross-sectional studies due to the lack of temporality, but prospective studies have not always controlled for sufficient covariates, such as socio-economic position, fluoride, and dietary exposure to sugar-rich foods and beverages (Arora et al., 2011).

One of the challenges in synthesising findings of studies of breastfeeding and ECC is the diversity of measurement and reporting of the exposure variable. Infant feeding practices are an inter-related set of behaviours and milk-feed types, which are difficult to measure simply, and challenging to depict as a single exposure variable. Duration of any breastfeeding is often used, which, if not analysed as a continuous variable, requires careful consideration of categorical cut points (Hector, 2011). In practice, most children receive a mix of breast milk and formula (AIHW, 2011; Cui et al., 2017), however the proportion of breast milk to formula consumed per day is difficult to estimate and therefore seldom included in measures of breastfeeding duration.

Other ways to measure and report breastfeeding as an exposure include ever versus never (Cui et al., 2017; Kato et al., 2015), exclusive or predominant breastfeeding versus formula and/or mixed feeding (Cui et al., 2017; Majorana et al., 2014; Tham et al., 2015), breast versus bottle feeding (Avila et al., 2015; Feldens et al., 2018), or other behavioural factors such as demand breastfeeding (Prakash et al., 2012), frequency of breastfeeds per day (Feldens et al., 2010b) or the presence or frequency of night-time breastfeeding (Perera & Ekanayake, 2010; Tham et al., 2015). Each of these variables may be further complicated by differences in how they are defined and measured (for further discussion, see 2.5.2 p. 60). For example, the provision of expressed breast milk via a bottle may not be adequately captured and represented in a binary breast versus bottle variable. This diversity makes pooling results for meta-analysis challenging.

The recent reviews varied in the number of included studies due to variations in aim and inclusion criteria. Tham et al. (2015) included 63 studies in the qualitative synthesis (11 cohort studies were the strongest study design), but quantitative investigations only included 14 of these (3 cohort), divided across 3 meta-analyses due to diversity of study methods and reporting. In contrast, only 7 studies were included for qualitative synthesis and 2 (both cross-sectional) for meta-analysis in the review by Avila et al. (2015). Cui et al. (2017) did not provide a qualitative synthesis, but included a total of 35 studies (11 cohort) across 4 meta-analyses. Even among the studies that remained for meta-analysis, differences in measurement and reporting of breastfeeding practices resulted in further sub-grouping by both Tham et al. (2015) and Cui et al. (2017), with at least 3 and at most 22 studies pooled for analysis within each group. With no meta-analysis of breastfeeding factors, Moynihan et al. (2019) included 21 studies (1 cohort) in a narrative review of breastfeeding beyond 1 year but less than 2 years, and 8 studies (2 cohort) when looking at breastfeeding beyond 2 years. Table 2.2 presents these subgroup analyses and a summary of results.

It is notable that these systematic reviews, published within 5 years of one another, vary widely in the number of included studies. This reflects the inconsistency of study methods used to investigate the relationships between breastfeeding practices and ECC (see 2.4.2.3). There are also discrepancies in how the studies have been classified, in terms of study type and in their quality scores. Cui et al. (2017) mis-identified 2 cross-sectional studies as birth cohorts (Nunes et al., 2012; Retnakumari & Cyriac, 2012), and Tham et al. (2015) mis-identified 1 cohort study as cross-sectional (Majorana et al., 2014). The mis-identified cohort study describes a ‘retrospective’ approach in the abstract, title and aim, which may explain the inconsistency in Tham et al. (2015); and why it was not mentioned by Moynihan et al. (2019) as either an included or excluded study. Four studies that were included by Tham et al. (2015) were not mentioned at all in the review by Cui et al. (2017) (Kramer et al., 2009; Ollila & Larmas, 2007; Tada et al., 1999; Thitasomakul et al., 2009), neither as included or excluded studies, suggesting they were not identified by the search strategy, or excluded at an earlier stage of the search.

Table 2.2 Summary of recent systematic reviews of breastfeeding and ECC

Exposure[a]	Paper	Included studies	Meta-analysis or Narrative review result[b]
Ever BF v Never BF	Cui 2017	22 (6 CS) I^2 85.6%	↓ ECC ever BF [OR = 0.77, 95% CI: 0.61–0.97, $p = 0.026$]
More BF v Less or never BF, up to 12Mo	Tham 2015	5 (1 CS) I^2 86.8%	↓ ECC more BF up to 12Mo [OR = 0.50, 95% CI: 0.25–0.99, $p < 0.001$]
More BF v Less but not never, up to 12Mo	Tham 2015	3 (1 CS) I^2 0%	N-A ECC more BF up to 12Mo [OR = 0.92, 95% CI: 0.69–1.23, $p = 0.645$]
Exclusive BF v Bottle feeding	Cui 2017	10 (4 CS) I^2 92.0%	N-A ECC exclusive BF [OR = 0.68, 95% CI: 0.35–1.31, $p = 0.248$]
BF v cow's (or similar) milk, > 12Mo	Moynihan 2019	0	
BF v cow's (or similar) milk, > 2Y	Moynihan 2019	0	
BF ≥6Mo v <6Mo	Cui 2017	8 (3 CS) I^2 82.2%	N-A ECC BF ≥ 6Mo [OR = 1.13, 95% CI: 0.83–1.53, $p = 0.428$]
BF ≥ 12Mo v < 12Mo	Cui 2017	14 (4 CS) I^2 90.5%	↑ ECC BF ≥ 12Mo [OR = 1.86, 95% CI: 1.37–2.52, $p < 0.001$]
	Tham 2015	7 (2 CS) I^2 69.3%	↑ ECC BF ≥ 12Mo [OR = 1.99, 95% CI: 1.35–2.95, $p = 0.003$]
BF ≥ 12Mo v < 12Mo, up to 2Y	Moynihan 2019	21 (1 CS)	N-A ECC BF ≥ 12Mo up to 2Y (narrative)
BF ≥ 2Y v < 2Y	Moynihan 2019	8 (2 CS)	N-A/↑ ECC BF ≥ 2Y (narrative, low quality, inconsistent between the 2 cohort studies)
More nocturnal BF v less, subset BF > 12Mo	Tham 2015	5 (1 CS) I^2 77.1%	↑ ECC more nocturnal BF [OR = 7.14, 95% CI: 3.14–16.23, $p = 0.002$]

ECC Early Childhood Caries CS Cohort Studies BF Breastfeeding v versus Mo Months of age Y years of age OR Odds Ratio CI Confidence Interval I^2 Heterogeneity score

[a] Unless otherwise specified, exposure included studies in children up to 6 years of age (Cui et al., 2017; Moynihan et al., 2019) or with no age limit (Tham et al., 2015)

[b] ↑increased ECC; ↓ decreased ECC; N-A no association

Cui et al. (2017) conducted further investigations via subgroup analysis of confounders, tests for heterogeneity and publication bias, and sensitivity analysis by the removal of one publication at a time to investigate impact on overall results. The authors found that the more recent studies had more homogeneous findings than older studies, which may be due to study design methods becoming more consistent, improved standardisation of definitions and measurement methods, and improved use of multivariable analysis, controlling for relevant covariates (Cui et al., 2017). They also observed that associations were more pronounced when looking at studies with a higher quality score (eg Newcastle-Ottawa Scale ≥ 6), a sample size over 500 children, measuring ECC between 3 and 6 years of age (rather than earlier), published after 2010, and using adjusted odds ratios instead of simple (unadjusted) analyses. Similarly, the narrative review by Tham et al. (2015) observed that findings were consistent among the studies that controlled for relevant covariates.

These reviews concur that there appears to be a protective effect of breastfeeding in early life, probably to around 6 months of age, and a detrimental effect from prolonged breastfeeding, which is more pronounced when regularly practicing night-time feeding. The reviews are inconsistent in their determination of 'prolonged', with Tham et al. (2015) concluding that caries risk was increased if breastfeeding continued beyond 1 year of age, without investigating any higher cut-points. Moynihan et al. (2019) did explore this, finding that caries risk only increased if breastfeeding continued beyond the second year of life, but not if it ceased between 1 and 2 years.

The latest publications included in these reviews are from October 2014 (Tham et al., 2015), December 2015 (Cui et al., 2017) or August 2017 (Moynihan et al., 2019). To identify any subsequent cohort studies or Randomised Controlled Trials (RCT), a search was performed in PubMed Central using a similar strategy to those outlined in Cui et al. (2017) and Tham et al. (2015), with the date range 1 August 2017 to 1 September 2019 (Table 2.3). The titles and abstracts of 29 potential articles were reviewed. A citation search was also performed on the three review articles, providing a further 14 abstracts for review. Of these 43 publications, 1 cohort study (Feldens et al., 2018) and 1 RCT (Birungi et al., 2017) were identified as likely to be included in future reviews and meta-analyses of infant feeding and ECC, and are included in the discussions that follow. Those excluded comprised of review articles, letters to the editor, studies with exposures or outcomes other than breastfeeding and ECC, studies of caries in older children and/or cross-sectional studies.

Table 2.3 Search strategy PubMed, September 2019

	Terms
#1	breast feeding [MeSH]
#2	breast milk [MeSH]
#3	breast AND feed* [All fields]
#4	breastfe* OR breast-fe* [All fields]
#5	infant fe* [All fields]
#6	Infant nutrition* [All fields]
#7	#1 OR #2 OR #3 OR #4 OR #5 OR #6
#8	dental caries [MeSH]
#9	tooth decay [All fields]
#10	“early childhood caries” [All fields]
#11	“nursing caries” OR “bottle caries” [All fields]
#12	#8 OR #9 OR #10 OR #11
#13	#7 AND #12
Filter	*human
Filter	published 1 August 2017 – 1 September 2019

2.4.2.2 Randomised Controlled Trials of Breastfeeding

Breastfeeding RCTs are limited in their approach, as it is unethical to withhold breastfeeding from an infant. Two recent studies have attempted to take an RCT approach to breastfeeding, by randomising access to breastfeeding promotion, however they did not focus on ECC as a primary outcome. The Promotion of Breastfeeding Intervention Trial (PROBIT) was a cluster-randomised trial of interventions to promote breastfeeding, conducted in Belarus (Kramer & Kakuma, 2012; Kramer et al., 2009; Kramer et al., 2007). In Ugandan communities, the PROMISE-EBF study used cluster-randomised peer counselling to promote exclusive breastfeeding (Birungi et al., 2017; Birungi et al., 2015). Dental caries was a secondary outcome for both studies, with the primary focus on testing the effectiveness of the promotion strategies. Both trials reported higher breastfeeding in the intervention group than the control group, but found no significant differences in dental caries between the two groups (Birungi et al., 2015; Kramer et al., 2007).

A key limitation of these studies is that because breastfeeding behaviours cannot be withheld from the control group, only promoted to the intervention group, it is not possible to tightly control the exposure of the study participants. This does not always result in different breastfeeding rates between the two groups. Although an initial difference in breastfeeding prevalence at 2 years of age was observed in

PROMISE-EBF, at 5 year follow up there was no difference in mean breastfeeding duration between the control and intervention groups (Birungi et al., 2015).

In the initial analysis, neither study found an association between breastfeeding promotion and ECC, however neither assessed the association between actual breastfeeding practices and ECC, only comparing ECC prevalence between the two trial arms. A subsequent nested analysis of PROBIT did investigate actual breastfeeding, and found no difference in ECC risk between children exclusively breastfed to 3 months versus 6 months of age (Kramer et al., 2009). Similar work in PROMISE-EBF found a protective effect of exclusive breastfeeding to 6 months of age (yes versus no) on ECC, and no association between ECC and any breastfeeding beyond 2 years of age versus less than 2 years (Birungi et al., 2017). These results are particularly notable given the long breastfeeding duration (49% of children were breastfed beyond 2 years) and high rates of exclusive breastfeeding (64% were exclusively breastfed to 6 months) in this cohort (Birungi et al., 2017).

Two RCTs have considered ECC as a primary outcome and included breastfeeding advice in the intervention and analysis. These used either home visit advice on feeding and weaning for caries prevention (Feldens et al., 2010a; Feldens et al., 2007), or health worker training for giving feeding advice (Chaffee et al., 2014; Feldens et al., 2018) in their intervention group. The studies had mixed findings with regard to breastfeeding, and are further discussed with the prospective cohort studies.

2.4.2.3 Prospective Cohort Studies

A summary of recent cohort studies (2010 onwards) is provided in Table 2.4. As explored in the reviews by Moynihan et al. (2019), Cui et al. (2017) and Tham et al. (2015), the studies mostly support the hypothesis that the relationship between breastfeeding duration and ECC is u-shaped (Tanaka et al., 2013), with reduced ECC with breastfeeding to 6 months of age compared with less or no breastfeeding (Hong et al., 2014; Majorana et al., 2014), no association with breastfeeding 1 to 2 years (Feldens et al., 2010b; Peres et al., 2017; Tanaka et al., 2013) and increased ECC with breastfeeding after 2 years of age (Chaffee et al., 2014; Peres et al., 2017). Studies that investigated frequency of feeding at 1 year found increased ECC with greater number of breastfeeds per day (Feldens et al., 2010b; Feldens et al., 2018).

Table 2.4 Summary of recent cohort studies

Study	Results[a]	Study design, analysis *n*; Location	Exposure [prevalence]; categories	Outcome [method]; age at dental examination	ECC prevalence	FI[b]	Statistical method; Confounders	Diet variable/s; assessment method/s	Included/Excluded[c]; NOS rating Tham 2015	Cui 2017	Moynihan 2019
				Duration studies							
Peres 2017	↑ ECC with BF ≥24Mo and ↑ S-ECC with BF ≥24Mo N-A ECC BF ≥12Mo cf BF <12Mo	Birth cohort; *n* = 1129; Pelotas, Brazil; 2004-9	Prolonged BF ≥24Mo [22.9%] BF 0-12Mo (ref), 13-23Mo, ≥24Mo;	Mean dmfs & presence of S-ECC (dmfs ≥6) [WHO]; 4 years of age	48% (dmfs ≥1) 23.9% (S-ECC)	Yes	Marginal Structural Model; Income, maternal education, maternal age, night bottle feeds, sugar consumption	Freq of Sugar; 24Mo (food list - past 24-Hr), 48Mo (same list +SSB), 5Y (single Q)	N/A	N/A	I
Nirunsittirat 2016	N-A ECC with any BF ≥18Mo cf BF <6Mo ↓ ECC with full BF 6-11Mo N-A ECC with any BF 6-11Mo cf BF <6Mo	Birth cohort; *n* = 556 Khon Kaen, Thailand; 2001-5	Prolonged BF ≥18Mo [33.8% any BF ≥18Mo] Any BF and full BF <6Mo (ref), 6-11Mo, 12-17Mo, ≥18Mo	Mean dmfs & presence of ECC (dmfs ≥1) [WHO]; 3–4 years of age	88.1% (ECC)	No	Negative Binomial Regression (un+adj OR); Income, maternal age, sweet intake freq, brushing freq, child's sex, age commenced bottle feeding	Freq of consuming sweets 3Y self-report, methods not further detailed	N/A	N/A	E[d]
Chaffee 2014	↑ S-ECC with BF ≥24Mo cf BF <6Mo N-A S-ECC BF ≥24Mo cf BF 6-23Mo	birth cohort nested in cluster RCT; *n* = 715; Porto Alegre, Brazil; 2008-11	Prolonged BF ≥24Mo [29.1%] <6Mo (ref), 6-11Mo, 12-23Mo, ≥24Mo	Presence of S-ECC (1 or more affected maxillary anterior teeth or dmfs ≥4) [WHO]; 3 years of age	34.3% (S-ECC)	Yes	Marginal Structural Model (adjusted PR); nesting trial allocation, maternal age, education, pre-preg BMI, parity, social class, smoking, child age, sex, feeding habits, bottle use, length-for-age Z-score	2 food index questionnaires (food list), created for this population; no validation reported	I; 8	I; 8	I

Continued

Tanaka 2013	N-A ECC with BF ≥18Mo and N-A S-ECC BF ≥18Mo cf BF <6Mo Non-significant u-shaped trends ↑ ECC longer BF duration (quadratic trend $p < 0.05$)	Birth cohort; *n* = 315; Osaka, Japan; 2001-07	Prolonged BF ≥18Mo [22%] <6Mo (ref), 6-11Mo, 12-17Mo, ≥18Mo	Presence of ECC (dft ≥1) & S-ECC (≥1 affected maxillary anterior teeth or dft ≥4) [WHO, modified to excl. missing]; 3-4 years of age	24% (ECC) 7% (S-ECC)	No	Logistic Regression (un+adjusted OR); Mat age, smoking; income; education; child's sex; birth weight; age first tooth; tooth brushing; use of fluoride; regular dental checkups; age at oral exam; bottle with sweet liquids; bottle to sleep, weaning age.	Bottle use with sweet liquids other than milk and age of introduction of solids; self-report, methods not further detailed	I; 8	I; 8	E[d]
Feldens, 2010	N-A ECC BF ≥ 12Mo cf BF <12 Mo ↑ S-ECC ≥7 BFs per day and ↑ S-ECC 3-6 BFs per day cf 0-2 BFs per day	birth cohort nested in cluster RCT; *n* = 331; Sao Leopoldo, Brazil; 2001-06	Prolonged BF ≥12Mo [52%] <12Mo (ref), ≥12Mo Frequency of BFs at 12Mo [34% ≥7/day] 0-2 (ref), 3-6, ≥7 BFs per day	Presence of S-ECC (≥1 affected maxillary anterior teeth or dmfs ≥5) [NIH]; 4 years of age	37% (S-ECC)	Yes	Poisson regression (un+adjusted RR); maternal education, BF freq, number of meals & snacks per day, bottle use for fruit juice/soft drinks, high density sugar, n teeth at 12 Mo. BF duration excluded from final model as not sig stepwise in adj model.	Daily *n* meals and snacks, high sugar density foods intake Questionnaires at 6Mo and 12Mo (face validity with n=16); 24-hour recall at 12Mo. Collected by trained student nutritionists, supervised by an experienced nutritionist	I; 10	I; 10	E[d]

Continued

ECC Early Childhood Caries BF Breastfeeding BM Breast milk v Versus Mo Months of age Y years of age NOS Newcastle-Ottawa Scale for assessing quality (out of 10 unless specified)

[a] ↑increased ECC; ↓ decreased ECC; N–A no significant association

[b] Fluoride coverage in water supply at recommended levels (0.6-1.1 mg/L)

[c] E - paper included in article but excluded from review; N/A - paper not available at time of article; N/I - paper available at time but not mentioned in article

[d] Listed in review supplementary table as excluded due to either "Intervention or exposure did not meet the inclusion criteria" or "study design did not meet the inclusion criteria"

Study	Results[a]	Study design, analysis *n*; Location	Exposure [prevalence]; categories	Outcome [method]; age at dental examination	ECC prevalence	FI[b]	Statistical method; Confounders	Diet variable/s; assessment method/s	Included/Excluded[c]; NOS rating Tham 2015	Cui 2017	Moynihan 2019
Ever v Never, or more v less											
Bernabé 2017	N-A ECC with BF ≥6Mo cf never BF	Birth cohort; *n* = 1102; Dundee Scotland; 1993-8	BF ≥6Mo [17.6%] Never BF (ref), <6Mo, ≥6Mo	4-Y caries increment, based on dmfs index [methods not specified] at 1, 2, 3 & 4 years of age	Not stated Mean dmfs ranged from 0.5 at 1Y to 3.57 at 4Y	No	Linear Mixed Effects Model (4-Y caries increment); child's age, sex, birth order, birth weight, BF duration, toothbrushing, maternal smoking, education and age, employment, marital status, area deprivation	Nil	N/A	N/A	E[d]
Peltzer 2015	N-A S-ECC BF 1-3Mo cf Never BF Data for BF ≥4Mo not reported	Birth cohort; *n* = 597; Mueang Nann Thailand; 2000-05	BF at 1-3Mo [26.1%] Never BF (ref), 1-3Mo, ≥4Mo (not reported)	Presence of S-ECC (1 or more affected maxillary anterior teeth or dmfs ≥4) [WHO]; 3 years of age	44.1% (S-ECC)	Inconsistent; natural sources only	Logistic Regression (un+adjusted OR); Final model unclear, presumed as drinking water source, maternal education, sex, bottle feeding at night	Sweet intake not included in final model; 5-item food list at 3Y, no validation reported	N/A	I; 9	E[d]
Kato 2015	↑ caries with BF ≥ 6-7Mo cf BF <6-7Mo N-A / ↑ caries with Predominant or any BF at 6-7 Mo cf never BF N-A caries if never BF cf Ever BF	Population monitoring survey (annual); *n* = 39 631 (2.5Y) - 35 754 (5.5Y); Japan; 2001-7	Never BF [<6%] & AnyBF at 6-7Mo [54%] & 'Exclusive' (predominant) BF at 6-7Mo [22%]; Exclusive formula 6-7Mo (ref), mixed feeding to 1-2Mo, 3-5Mo, 6-7Mo, 'Exclusive' BF to 6-7Mo	Dental treatment for caries past 12Mo; [Self report] at 2.5, 3.5, 4.5 & 5.5 years of age	self-reported caries ranged from 7% at 2.5Y to 36.5% at 5.5Y	No	Logistic Regression (un+adjusted OR); Birth weight, sex, parity, maternal age at delivery, maternal education, maternal smoking status, marital status at delivery, family, region of birth, residence	Nil	N/A	I; 7	E[d]

Continued

Hong 2014	↑ ECC with BF <6Mo cf BF ≥6Mo	Birth cohort; *n* = 509; Iowa, USA; 1992-2004	BF <6Mo [29%] <6Mo, ≥6Mo (ref)	Presence of ECC (prevalence & dfs) on primary second molars; [methods not specified] 5&9 years of age	16% (ECC on molars) at 5Y; 36% at 9Y	Varied, adjusted for in model	Logistic Regression (un+adjusted OR); Birth weight, parent education, family income, home tap water fl level, soda intake, tooth brushing freq, enamel hypoplasia	Daily soda intake (not specified whether child or parent); self report methods not further detailed	I; 8	I; 7	E[d]
Majorana 2014	↓ ECC prevalence and severity with greater BF at 6Mo cf formula	Birth cohort; *n* = 2395; Brescia, Italy; 2008-10	'Exclusive' (predominant) BF at 6 Mo [24.6%] Exclusive formula 0-6Mo (ref), high BF mixed feeding (58-99% BF), low BF mixed feeding (1-57% BF), 'Exclusive' BF 6Mo	ECC severity (No caries, Low (ICDAS 1–3) Moderate (4) High (5-6) caries) [ICDAS]; 2-2.5 years of age	80.84% ICDAS ≥0 low 48.6%, moderate 27.5%, high 4.3%	No	Ordinal regression; Smoking, housing cost, sweet dietary habit	Child consumption of sweet beverages other than milk at 6Mo and 9Mo; self report methods not further detailed	I; 4/7	I; 9/10	N/I (but would be E-age)
				Frequency of feeds (see also Feldens 2010)							
Feldens 2018	↑ ECC w high frequency BF, ↑ S-ECC with high freq BF ↑ ECC with high freq mixed, N-A S-ECC high freq mixed N-A ECC high freq bottle, N-A S-ECC high freq bottle cf low frequency feeding (breast or bottle)	birth cohort nested in cluster RCT *n* = 345 Porto Alegre, Brazil; 2008-11	Freq bottle & BF at 12Mo [25% high freq BF]; Low freq bottle or BF (ref), mixed feeding, High-freq bottle feeding only (no bf), High freq BF only (no bottle) Bottle feeding any liquid incl. water (Expressed BM not specified).	Presence of ECC (d1mfs ≥1) & Presence of S-ECC (1 or more affected maxillary anterior teeth or d1mfs ≥4) [WHO modified to incl non-cavitated lesions]; 3 years of age	54.8% (dmfs ≥1) 32.5% (S-ECC)	Yes	Poisson regression (un+adjusted RR); child age, child sex, maternal age, maternal education, household social class, allocation status in the nesting trial, and total carbohydrate intake	Daily feeding freq (*n* eating occasions) and total carbohydrate intake two 24-hour recalls at 12Mo; multiple pass method.	N/A	N/A	N/A

ECC Early Childhood Caries BF Breastfeeding BM Breast milk v Versus Mo Months of age Y years of age NOS Newcastle-Ottawa Scale for assessing quality (out of 10 unless specified)

[a] ↑increased ECC; ↓ decreased ECC; N–A no significant association

[b] Fluoride coverage in water supply at recommended levels (0.6-1.1 mg/L)

[c] E - paper included in article but excluded from review; N/A - paper not available at time of article; N/I - paper available at time but not mentioned in article

[d] Listed in review supplementary table as excluded due to either "Intervention or exposure did not meet the inclusion criteria" or "study design did not meet the inclusion criteria"

There were some contradictions in these findings. For example, Chaffee et al. (2014) found higher severe-ECC with those breastfed beyond 2 years, compared to those breastfed less than 6 months, but not when compared to those breastfed between 6 months and 2 years. This is inconsistent with the proposed u-shaped curve. Similarly, Kato et al. (2015) found increased caries among those breastfed for greater than or equal to 6 months, compared to those breastfed for less than 6 months. This study is notably limited in the measure of caries, using maternal report of whether the child had received dental treatment for caries in the previous year. One study failed to contribute any evidence to the breastfeeding-ECC hypothesis, reporting findings for breastfeeding duration to only 3 months of age (Peltzer & Mongkolchati, 2015).

No two studies used the same exposure and outcome variable categories to investigate the relationship between breastfeeding and ECC, nor did they include the same covariates in multivariable analysis. The quality scores awarded by the reviews were moderate-to-high for several of these cohort studies, however the Newcastle Ottawa Scale indices are generic to all outcomes, and fail to capture a range of limitations specific to the investigation of breastfeeding and ECC. In particular, the systematic reviews by Tham et al. (2015) and Cui et al. (2017) did not list fluoride as an effect modifier when assessing study design quality, and only Tham et al. (2015) and not Cui et al. (2017) included sugars. The studies included in Table 2.4 vary greatly in their design, duration, exposures and outcomes, and the reported methods lack detail, making it difficult to ascertain methodological strengths and limitations.

Almost all included studies used standard methods to measure and report ECC, such as those provided by WHO (2013b) or the International Caries Detection and Assessment System (ICDAS) (Ismail et al., 2007), however two studies did not specify the methods used (Bernabé et al., 2017; Hong et al., 2014) and another relied on parent report of whether their child had visited a dentist for ECC treatment (Kato et al., 2015). Feldens et al. (2018) report modifying the WHO criteria to include non-cavitated lesions, which fits with the definition of ECC and is a key point of difference between the WHO and ICDAS classification systems (Braga et al., 2009). No other studies that used the WHO (2013b) criteria report making this modification, but they may have done so without reporting.

Another potential variation in ECC assessment methods is the approach to missing primary teeth, the loss of which increases with age. Of the studies included in Table 2.4, Hong et al. (2014) includes the oldest children, assessing caries at 5 and 9 years of age, beyond the defined age of ECC (up to 6 years). As children had lost many primary teeth at time of the 9 year dental exam, only primary second molars were used as indicator of caries, rather than looking at all teeth. Tanaka et al. (2013) report using a modified WHO criteria to exclude missing teeth from consideration, as they were unable to determine whether a tooth was missing due to caries extraction or for another reason. It is assumed that the remaining studies which do not specify their approach have assessed ECC based on all teeth, including those missing due to caries, as per the ICDAS and WHO methods.

Methods for assessing and reporting breastfeeding are even less consistent. Terminology is vague in most studies, with only two (Kato et al., 2015; Nirunsittirat et al., 2016) specifying whether the questions used to measure breastfeeding allowed for the WHO (2008) definitions to be used. Most studies appear to have used duration of any breastfeeding as the criteria, without investigating exclusivity, however Kato et al. (2015) and Majorana et al. (2014) considered formula and mixed feeding, in addition to predominant breastfeeding. Breastfeeding categories and cut points are also inconsistent, with some studies grouping duration at 0-12 months (Feldens et al., 2010b; Peres et al., 2017), while others separate 0-6 and 6-12 into two groups (Chaffee et al., 2014; Tanaka et al., 2013). The definition of ‘prolonged’ breastfeeding varies, with studies using greater than or equal to 1 year (Feldens et al., 2010b), 18 months (Nirunsittirat et al., 2016; Tanaka et al., 2013), or 2 years (Chaffee et al., 2014; Peres et al., 2017) as the cut-off for the top duration category. These variations also mean the reference category varies, with studies comparing breastfeeding for more versus less than 6 months, or more versus less than 1 year, or more than 2 years versus less than 1 year or less than 6 months.

These cohort studies have chiefly used very basic measures of sugars exposure, such as the consumption of sugar-sweetened beverages, but not foods (Hong et al., 2014; Majorana et al., 2014; Tanaka et al., 2013). Two studies did not control for sugars intakes at all (Bernabé et al., 2017; Kato et al., 2015). Four studies employed a brief food list or single question (Chaffee et al., 2014; Nirunsittirat et al., 2016; Peltzer &

Mongkolchati, 2015; Peres et al., 2017), which were not subjected to validity testing prior to use and are likely subject to substantial reporting bias (NIH & NCI, 2018).

Most studies provided little detail into dietary assessment methods, and only two studies indicated that validity testing of the dietary assessment tools was conducted (Feldens et al., 2010b; 2018). The earlier study only conducted face validity, completing a pilot test of the questionnaires among 16 mothers prior to implementation to the cohort, though the same study also administered a 24-hour dietary recall (Feldens et al., 2010b), which has been shown to have good validity when standard methods such as the multi-pass method are employed (NIH & NCI, 2018). The authors did not report whether the multi-pass method was used, though they did indicate that dietary assessors participated in a 12-hour training program, and received supervision and data checking throughout the data collection process. In the later study, Feldens et al. (2018) report the use of repeat 24-hour recalls to obtain dietary intake data via the multi-pass method.

Studies providing lower-level evidence, such as case-control and cross-sectional research, have similar discrepancies in design, exposures and outcomes, which further obscure the issue. Although some patterns have emerged, it is difficult to confidently draw conclusions about the relationship between breastfeeding and ECC due to these inconsistencies (Moynihan et al., 2019; Tham et al., 2015).

2.4.3 Emerging Hypothesis: Fluoride

Secondary analysis of the Australian National Child Oral Health Study, a large cross-sectional study, demonstrated that breastfeeding beyond 2 years of age was only associated with increased ECC among children living in areas without access to fluoridated mains water (Ha et al., 2019). This introduces an emerging hypothesis, that fluoride exposure may be sufficient to modify the effect of prolonged breastfeeding on ECC risk. The summary of cohort studies in Table 2.4 lists whether each cohort had access to public water fluoridation at the time of the study.

This hypothesis may explain why Kato et al. (2015) found increased caries among those breastfed for greater than or equal to 6 months, compared to those breastfed for less than 6 months, as the study population did not have access to fluoridated mains water. It does not explain why Peres et al. (2017) and Chaffee et al. (2014) found increased ECC among those who were breastfed for greater than or equal to 2 years in fluoridated areas, though it might be a reason for the finding by Chaffee et al. (2014) that there was no greater ECC risk when comparing those breastfed for greater than or equal to 2 years to those breastfed for between 6 months and 2 years.

Of the four studies in Table 2.4 that investigated duration of breastfeeding, three were conducted in areas with population water fluoridation (Chaffee et al., 2014; Feldens et al., 2010b; Peres et al., 2017), and the one that was not controlled for home fluoride use (Tanaka et al., 2013). None of these studies reported the effect of fluoridation on the relationship between breastfeeding and ECC, so conclusions cannot be drawn one way or the other.

The only recent cohort study to investigate fluoride directly did not support this hypothesis (Hong et al., 2014), however the breastfeeding duration categories were much lower than those investigated in the national survey (Ha et al., 2019). Hong et al. (2014) found that home water fluoridation was associated with reduced ECC in children breastfed between 0 and 6 months, but not those breastfed beyond 6 months.

This hypothesis is supported by the measured difference in cariogenic potential of formula made up with fluoridated versus non-fluoridated water (Cressey et al., 2009). The cariogenic potential of breast milk may be similarly reduced by the presence of fluoridated tap water, if it is given as a drink or used in the preparation of complementary foods.

2.4.4 Interpretation: Current Practice Guidelines

Discourse continues around how to interpret the current evidence for breastfeeding and ECC, especially in light of the extensive benefits of breastfeeding. As a result, some dental practice guidelines align with infant feeding recommendations to prioritise the benefits of breastfeeding, while others include cautionary statements that prioritise ECC risk. For example, in their policy statement on early childhood caries, the American Academy of Pediatric Dentistry recommend,

> "…avoiding frequent consumption of liquids and/or solid foods containing sugar, in particular… ad libitum breast-feeding after the first primary tooth begins to erupt and other dietary carbohydrates are introduced."
>
> (AAPD, 2016, p. 61)

This contradicts the WHO and UNICEF recommendation that breastfeeding should be provided on demand, day and night, as often as the child wants (WHO, 2019a).

In January 2018 the British Society of Paediatric Dentistry (2018) released their position statement on infant feeding, which included the recommendation that:

> "From 12 months of age, mothers who wish to continue breastfeeding should work closely with their health practitioners to minimise the potential risk of dental decay… Consideration should be given to reducing on demand and night-time feeds in light of the emerging evidence-base suggesting a potential link between these practices and complementary feeding after 12 months of age and dental decay."
>
> (British Society of Paediatric Dentistry, 2018, p. 8)

This was reported in the British Dental Journal (2018), and then followed by letters to the editor, questioning the appropriateness of this statement (Jones, 2018; Yeung, 2018), and a defence from the authors (Stevens et al., 2018). A statement was then issued by the UNICEF UK Baby Friendly Hospital Initiative (2018) in opposition to the position statement of the British Society of Paediatric Dentistry, including the observation that

> "The conclusions in the British Society of Paediatric Dentistry statement undermine WHO guidelines and cause confusion to health professionals and mothers who, by breastfeeding for longer, are in fact improving the health and wellbeing of their children."
>
> (UNICEF UK Baby Friendly Hospital Initiative, 2018, p. 2).

Two years on, the position statement remains publicly available on the British Society of Paediatric Dentistry website.

The recent WHO (2017c) Expert Consultation on Public Health Intervention Against Early Childhood Caries affirmed the WHO recommendations for breastfeeding (WHO, 2003b) and limiting free sugars intakes (WHO, 2015), called for more research into the relationship between breastfeeding and ECC, and did not make recommendations to limit breastfeeding in light of ECC (WHO, 2017c). Rather, the report highlights the health benefits of breastfeeding beyond 1 year, breastfeeding at night and breastfeeding on demand (WHO, 2017c).

Two further meeting summary articles, co-authored by many of the participating experts, appear to contradict one another on this matter. The first states,

> "Discontinuation of breastfeeding or replacement of breastfeeding by infant formula is not recommended."
>
> (Phantumvanit et al., 2018, p. 282).

The second, including several of the same experts as co-authors, states that health professionals should provide ECC preventation messages that include:

> "…avoiding baby bottle and breastfeeding beyond 12 months, especially if frequent and/or nocturnal."
>
> (Tinanoff et al., 2019, p. 242).

Regardless of the current interpretation, all guidelines call for more research, to resolve the deficits of the current evidence base.

2.5 Summary of Challenges in ECC Research to Date

Table 2.5 summarises the research design considerations that are pertinent to investigating the relationship between breastfeeding practices and ECC, and describes how the SMILE methods address these challenges.

Table 2.5 Summary of breastfeeding and ECC research design considerations; with related SMILE methods

	Summary of considerations	SMILE Methods
Study design	A prospective design of appropriate length to observe exposures and outcomes of interest	A prospective, birth cohort, to 7 years of age (SMILE and SMILE–2), however the analysis presented here concludes at the 2–3 year dental examinations.
	Recruitment that promotes generalisability of findings	Hospital recruitment, targeting all children born in Adelaide over a 1 year period. Oversampling from hospitals servicing mothers of low socio-economic position to address anticipated lower participation rate and higher levels of drop-out.
	Data collected at key time points to capture important exposures	Data collected at baseline, 3 months, 6 months, 1 year and 2 years of age. Additional data collection at 5 and 7 years of age not reported here.
Outcome variable ECC	Standard assessment methods and reporting, to reflect the definition of ECC	Protocol based on the NIDCR (2002) procedures manual and ICDAS protocol (Ismail et al., 2007), including non-cavitated lesions as per the ECC definition (AAPD, 2016). Standardised examination methods were outlined in the protocol, and conducted by dentists who undertook training and calibration activities.
	Measurement of ECC at an appropriate age; ideally after 3 years but before the primary maxillary anterior teeth are exfoliated (between 6-7 years) (Cui et al., 2017; Peres et al., 2018)	Dental examinations at 2–3 years (for this analysis: repeat examinations at 5-6 years of age are ongoing, not presented here).
Exposure variable breastfeeding	Standard data collection and reporting in line with the WHO (2008) definitions of BF	WHO (2008) definition of 'any breastfeeding' was the main variable used. Standard BF questions employed by the Australian Infant Feeding Survey (AIHW, 2011)
	BF duration categories: never BF, BF <6, 6-12, 12-24 and ≥24 months (Moynihan et al., 2019)	Minimal (0-<1), 1-6, 6-12 and ≥12 months used, due to low rates of never BF and BF beyond 24 months.
	Breastfeeding behaviours should be assessed comprehensively within the overall evaluation of infant feeding	Data collected include night-time breastfeeding, bottle feeding by liquid type (including expressed breast milk), age of introduction of solids, complementary foods, total diet and sugars intake, via methods used in the Australian National Infant Feeding survey (AIHW, 2011) or Perth Infant Feeding Studies I & II (Scott et al., 1997; 2006a).

	Summary of considerations	SMILE Methods
Covariates	Appropriate adjustment for relevant confounders and effect modifiers (Peres et al., 2018), using standard assessment and reporting methods:	Directed acyclic graphs were used to identify key confounders and effect modifiers.
	• Free sugars and other dietary variables (Chapter 3)	Questions about complementary foods in the 3 month and 6 month questionnaires came from the Australian National Infant Feeding survey (AIHW, 2011). Validated dietary assessment methods, including a 24-hour recall and 2-day estimated food record at 1 year, and an externally validated FFQ designed to assess free sugars intakes at 2 years of age. Dietary assessment at 1 and 2 years conducted by dietitians or student dietitians who undertook training, calibration and standardisation practices (NIH & NCI, 2018).
	• Socio-economic position	Maternal education (self-reported) and area-level socio-economic position (Index of Relative Socio economic Advantage and Disadvantage, determined from postcode at baseline).
	• Fluoride	At recruitment, participants all lived in areas with mains water fluoridation to recommended levels (NHMRC, 2017b), so fluoride was not adjusted for in the multivariable analysis.
Reporting	Dissemination in Q1 journals within both nutrition and dental fields, using standardised reporting methods	See 1.6 Dissemination, p. 8. STROBE (Vandenbroucke et al., 2007) and STROBE-NUT (Lachat et al., 2016) reporting guidelines used. Journals to date include The American Journal of Clinical Nutrition, Maternal and Child Nutrition, Nutrients, International Journal of Environmental Research and Public Health (Special Issue on *Epidemiology and determinants of dental caries in children*), Dentistry Journal, Maternal and Child Health Journal and BMC Public Health.
	Presentation of findings at conferences and seminars for the nutrition, dental and wider child health communities.	Conferences to date include International Association for Dental Research General Session, International Conference of Diet and Activity Methods, Maternal and Infant Nutrition and Nurture Conference (International), Dietitians Association of Australia National Conference and State symposium.

ECC: Early Childhood Caries SMILE: Study of Mothers' and Infants' Life Events affecting oral health BF: Breastfeeding WHO: World Health Organization ICDAS: International Caries Detection and Assessment System NIDCR: National Institute of Dental and Craniofacial Research FFQ: Food Frequency Questionnaire

2.5.1 Study Design

In order to investigate outcome risk, studies must have a prospective design with an appropriate length of follow up to measure the outcome (Cadmus-Bertram & Patterson, 2013). As RCTs of breastfeeding are limited in their design for ethical reasons, longitudinal cohort studies are appropriate (Cadmus-Bertram & Patterson, 2013; Peres et al., 2018). The duration of follow up is a critical consideration in ECC research design, due to the progressive nature of ECC, potential u-shaped relationship with breastfeeding over the first 2 years of life and beyond, and the exfoliation of primary teeth between 6 and 12 years of age (Irish & Scott, 2016). Studies that follow children for only the first year of life may not capture the full emergence of disease outcomes, and erroneously report null findings (Cadmus-Bertram & Patterson, 2013; Peres et al., 2018). Those that measure ECC after 6 years of age may produce an inaccurate caries score, particularly with regard to the classification of missing teeth (Peres et al., 2018).

Study methods should be designed to recruit a representative sample, and employ data collection methods that limit subject burden and minimise attrition and loss to follow up, which can hamper the generalisability of findings (Tham et al., 2015). In particular, strategies to account for the higher attrition rates commonly observed in participants of low socio-economic position should be employed, such as oversampling and/or targeted retention strategies (National Research Council & Institute of Medicine, 2004).

2.5.2 Study Tools and Methods

The first 2 to 3 years of life are characterised by rapid growth and development. Many health-related confounders and effect modifiers emerge during this time. Children’s diets completely transform from the neonatal, milk-based diet, through the complementary feeding process, to a pattern of eating that reflects the diets of other family members (NHMRC, 2012a). This includes the introduction of foods that have both cariogenic and carioprotective potential. Caries experience during these years is also confounded by the eruption of teeth and the commencement of oral hygiene practices (WHO, 2017c). In order to prospectively measure these changing exposures, data must be collected with a high enough frequency to capture the various stages of infant feeding, and the commencement of confounding behaviours.

Standardised methods for assessing and reporting ECC, breastfeeding and the relevant covariates should be used, based on accepted definitions. Dental examinations should follow standardised protocols, such as those set out by the International Caries Detection and Assessment System (ICDAS) (Ismail et al., 2007), WHO (2013b) or the National Institute of Dental and Craniofacial Research (NIDCR) (2002), and clearly explain any variations when reporting findings. Scoring methods (Figure 2.3) should follow either the ICDAS scores or dmft/s: a count of the number of decayed, missing (due to caries), and filled teeth or surfaces. Standard definitions of ECC and severe-ECC (AAPD, 2016) should be employed.

Figure 2.3 Standard scoring methods for early childhood caries: ICDAS and dmft/s

	Scoring for dmft/s[a]	**Scoring for ICDAS**[b]
Diagnostic criteria	A Sound B Caries C Filled, with caries D Filled, no caries E Missing due to caries F Fissure sealant G Fixed dental prosthesis abutment, special crown or veneer/implant	0 Sound tooth surfaces 1 First visual change in enamel 2 Distinct visual change in enamel 3 Initial breakdown in enamel due to caries with no visible dentin 4 Non-cavitated surface with underlying dark shadow from dentin 5 Distinct cavity with visible dentin 6 Extensive distinct cavity with visible dentin
Scoring	dmft/s: Sum of the primary teeth or surfaces scored as B, C, D or E	ICDAS recommends scoring cut-offs be determined by research need
Accepted classifications of ECC, S-ECC	ECC: dmfs ≥ 1 S-ECC 0-3 years: dmfs ≥ 1 S-ECC ≥ 3 years: dmfs ≥ 1 in primary maxillary anterior teeth, or dmfs ≥ 4 (age 3), ≥ 5 (age 4) or ≥ 6 (age 5)	ECC: ICDAS ≥ 1, ≥ 2 or ≥ 3 Severity based on highest recorded ICDAS score: No caries: ICDAS 0 or ≤ 1 Low: ICDAS 1–3 Moderate: ICDAS 4 High: ICDAS 5–6

[a] number of decayed, missing (due to caries), filled teeth or surfaces (WHO, 2013b, 2017c). Diagnostic criteria from WHO (2013b) listed; NIDCR (2002) use different criteria but result in same dmft/s scoring outcome
[b] ICDAS: International Caries Detection and Assessment System, version 2 (Ismail et al., 2007)
ECC: Early Childhood Caries S-ECC: Severe Early Childhood Caries

Similarly, the WHO (2008) definitions of breastfeeding should be used in measurement and reporting (Figure 2.4). If 'any breastfeeding' is used as the measure, reporting should clearly describe this term, with reference to the WHO (2008) definitions. If 'exclusive breastfeeding' is used, an investigation of whether any other foods or liquids have been provided to the infant in addition to breast milk is required, and, if so, details of what kinds of foods and liquids must be obtained. Data coding for breastfeeding variables need careful consideration, particularly regarding the selection of cut-points for breastfeeding duration (Peres et al., 2018), and grouping of breast and bottle feeding behaviours.

Figure 2.4 World Health Organization breastfeeding definitions, summarised in the Australian Infant Feeding Guidelines

Category of infant feeding	Requires that the infant receive	Allows the infant to receive	Does not allow the infant to receive
Exclusive breastfeeding	Breast milk (including milk expressed or from wet nurse or breast milk donor)	Prescribed drops or syrups (vitamins, minerals, medicines)	Anything else
Predominant (Full) breastfeeding	Breast milk (including milk expressed or from wet nurse or breast milk donor) as the predominant source of nourishment	Liquids (water, and water-based drinks, fruit juice, oral rehydration solutions), ritual fluids and drops or syrups (vitamins, minerals, medicines)	Anything else (in particular: non-human milk, solid foods, food-based fluids)
Complementary breastfeeding	Breast milk and solid or semi-solid foods	Any food or liquid including non-human milk	
Any breastfeeding	Some breast milk	Any food or liquid including non-human milk	
Ever breastfed	Received breast milk or colostrum on at least one occasion		
Bottle-feeding	Any liquid from a bottle with nipple/ teat	Also allows breast milk by bottle	

Source: National Health and Medical Research Council (2012a, p. 129), adapted from (WHO, 2008)

Methods for assessment and reporting of covariates should also be standardised, and selected *a priori*, based on the literature (Nelson & Margetts, 1997). Peres et al. (2018) recommend the use of Directed Acyclic Graphs (DAG) to identify key covariates for ECC, to reduce residual confounding and ensure only those variables associated with the outcome of interest are included. Usage of DAG in dental research is increasing (Peres et al., 2018), which may help to reduce the inconsistent selection of confounders between studies. Socio-economic position (particularly maternal education and/or household income), child age and usual intake of sugars are consistently recognised as the important confounders for the breastfeeding and ECC relationship (Ha et al., 2019; Peres et al., 2018; Tham et al., 2015). Fluoride is an effect modifier (Moynihan & Kelly, 2014) and should be included in studies where exposure to fluoridated mains water varies within the cohort. Oral health behaviours are not included as a covariate as they are not associated with breastfeeding, except via other confounders such as socio-economic position (Ha et al., 2019; Peres et al., 2018).

In Australia, nationally derived, area-level indices of socio-economic advantage and disadvantage can be obtained from the Australian Bureau of Statistics, based on residential postcode (ABS, 2013). These are derived from census data, based on principal component analysis of relevant socio-economic variables. Although not an individual measure, these indices provides an easily obtained, robust variable, that is unaffected by social desirability or other reporting biases (Choi & Pak, 2005; Macintyre & Anderson, 1997).

2.5.2.1 Dietary Assessment Methods

Of particular importance are the methods used to assess the child’s diet. Dietary assessment is complex, and dental studies are limited by a lack of consistency and precision of approaches used for measuring dietary intakes and food behaviours (see 2.4.2.3) (Moynihan & Kelly, 2014; Valaitis et al., 2000). It has been difficult to accurately capture free sugars intakes due to the absence of validated dietary assessment tools for this age group (Evans et al., 2013b). Dietary assessment methods should be comprehensive, and follow evidence-based guidelines for development, validity testing, and standardisation of data collection and entry (including protocol design, and the training and calibration of researchers) (Kirkpatrick et al., 2019; NIH & NCI, 2018; Thompson & Subar, 2013). Newly designed dietary assessment tools should be validated prior to use, and existing tools should be calibrated to each new cohort (Kirkpatrick et al., 2019; NIH & NCI, 2018; Thompson & Subar, 2013).

For sugars variables in dental research, the WHO (2015) definition of free sugars should be used (see 2.3.1). Measuring usual free sugars intakes requires either a short-term, total diet measure, such as a food record or repeat 24-hour recalls; or a longer-term, targeted intake tool, such as a food frequency questionnaire or screener (NIH & NCI, 2018). Short-term, total diet measures tend to have high subject burden, and substantial resource requirements for collection and data entry (NIH & NCI, 2018), although standard methods for conducting 24-hour recalls are already established (ABS, 2014b) Due to the lower subject and researcher burden, the food frequency questionnaire is considered the most appropriate data collection method for large, prospective studies, however it must be tailored to both the population and outcomes of interest, which requires resource investment in development and validation prior to use (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). A small calibration sub-study can be used if an appropriate tool has already been developed for a similar cohort (NIH & NCI, 2018), but this has not yet occurred for free sugars intakes of young children.

Regardless of method, childhood dietary intake is particularly challenging to measure (Thompson & Subar, 2013). Young children cannot self-report, so proxy reporting is used to collect the data from a parent or caregiver (Magarey et al., 2011; Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013). Surrogate reporters may not have complete knowledge of their child's usual diet, as other caregivers and child-care providers participate in food provision (Livingstone et al., 2004; Ortiz-Andrellucchi et al., 2010). Social desirability bias may influence a parent's report of their child's intake, particularly in relation to foods that are perceived as unhealthy (Börnhorst et al., 2012; Radnitz & Todd, 2016).

Estimating intakes of young children is particularly difficult due to the greater frequency of eating occasions, smaller portions, and faster changes to appetite and food preferences than older children and adults (Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013). This makes it difficult for parents to report 'typical' patterns of eating, and to estimate portion sizes. Toddlers also produce more plate waste than adults (Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013), which may be dispersed across the table, floor, clothing, family dog etc. Amorphous foods (such as rice, custard, juice) are more difficult to estimate than those with a defined unit (such as slice of bread, piece of fruit), and smaller portion sizes are more likely to be overestimated (Thompson & Subar, 2013), further encumbering the accuracy of surrogate reports.

Appropriate selection and validity testing of dietary assessment methods can minimise the impacts of these challenges. Combining multiple assessment methods can help obtain an overall diet picture, and account for the different types of bias in each method (NIH & NCI, 2018). Tools that allow for free-entry of portion size, or offer a range of small size options, can reduce the overestimation of foods consumed by toddlers via small, frequent meals and snacks. Because pre-specified food lists narrow the generalisability of food frequency questionnaires, validity should be assessed in a similar population and age to the study cohort (NIH & NCI, 2018).

When selecting or designing dietary assessment methods for this age, contributions of commercial infant and toddler foods to the diet must also be considered. These foods are specific to young children and require particular attention as a rapidly growing market (IBISWorld Australia, 2017). Ingredient profiles are unique to these products, and those marketed to children under 1 year of age are covered by a separate food standard to other foods (see 2.3.3.3) (Australian Government, 2017b). Studies report high levels of total and added sugars in commercial ready-to-feed infant and toddler foods in the United States (Maalouf et al., 2017), Canada (Elliott, 2011), and the United Kingdom (García et al., 2013). An Australian commercial infant food market review found lower levels of added sugars than studies in the United Kingdom and Canada, but similarly high total sugars, noting the presence of fruit purees and juices as sweeteners in Australian products (Dunford et al., 2015). If the (WHO, 2015) definition of free sugars had been employed, the fruit juice used in these products would have contributed towards the ‘added’ sugars count. In recent years, a commercial toddler food market has emerged, differentiating from infant foods by being promoted for children between 1 and 5 years of age. Commercial infant and toddler foods have minimal presence in Australian national food composition databases (FSANZ, 2014, 2019a), and are not included in dietary assessment materials developed for older children or adults. Dietary assessment for children under 5 years of age should include these foods in questionnaires and ensure they are accounted for within the food and nutrient database used to analyse the data.

Some of the challenges in ECC research to date reflect a lack of cross-disciplinary collaboration, resulting in dietary studies that do not capture dental risk factors, and dental studies that oversimplify dietary assessment. As dietary assessment is a branch of nutrition research, dental research teams do not always have the resources or nutrition expertise required to perform dietary assessment or undertake validity studies. Likewise, the dental examinations are highly specialised, requiring qualified and trained dental practitioners. A multidisciplinary study team is well-placed to overcome many of these challenges (Valaitis et al., 2000).

2.6 How the Study of Mothers' and Infants' Life Events Affecting Oral Health Addresses These Challenges

As indicated in Table 2.5 (p. 58), SMILE methods follow these design considerations. The project is managed by a multidisciplinary team of chief investigators with backgrounds in dentistry, nutrition and epidemiology. The study was developed based on an extensive review of the current literature, a significant proportion of which is published by members of the study team in their respective fields.

Participants were recruited from the major maternity hospitals in Adelaide, South Australia, over a 1-year period, in order to obtain a representative sample. The sampling period for hospitals servicing mothers of low socio-economic position had a duration longer than those in more advantaged areas, in order to over-sample participants of low socio-economic position, to account for the anticipated lower participation rate and higher attrition.

Data relating to key risk factors for ECC were collected at baseline, 3 months, 6 months, 1 year and 2 years of age, using age-specific dietary and oral health instruments. The methods and data collection instruments have been adapted from those used by the CIs in recent related studies: including the Perth Infant Feeding Studies I and II (Scott et al., 1997; Scott et al., 2006a), the Dunedin Longitudinal Cohort (Thomson et al., 2004), and the Iowa Fluoride Study (Levy et al., 2003). Standard definitions for breastfeeding (WHO, 2008) and free sugars (WHO, 2015) are used in data collection and reporting.

Baseline characteristics, including maternal education, were collected at recruitment. Postcode at recruitment was used to determine area-level socio-economic position (IRSAD), and confirm that all study participants lived in areas with fluoridated mains water to recommended levels (NHMRC, 2017b). Data regarding main drinking water sources were obtained, including type of filter if used, in order to identify participants who were actively avoiding fluoride for sensitivity analysis. Copies of the questions from SMILE that provided data used in this thesis are provided in Appendix C.

The dental examinations are based on methods developed by the Australian Research Centre for Population Oral Health, and used in the Australian National Child Oral Health Study (Do & Spencer, 2016). These follow examination protocols outlined in NIDCR (2002) protocol and ICDAS (Ismail et al., 2007). The NIDCR (2002) dmfs scoring criteria are used, incorporating non-cavitated lesions to produce a total caries experience score that aligns with the definition of ECC (AAPD, 2016). Dental examiners participated in training and calibration exercises in order to standardise assessment procedures. The analysis presented here concludes at the dental examinations conducted when the children were 2–3 years of age. Additional funding was awarded to follow the cohort until at least 7 years of age, and further dietary assessments and dental examinations are being conducted at 5-6 years of age.

As the diets of infants are predominantly milk-based between birth and 6 months of age, dietary assessment during this period can be relatively brief. Questions about breastfeeding practices in all questionnaires, and complementary foods in the 3 month and 6 month questionnaires, came from the Australian National Infant Feeding survey (AIHW, 2011) and the Perth Infant Feeding Studies I and II (Scott et al., 1997; Scott et al., 2006a). Evaluation of infant feeding included questions regarding duration of breastfeeding, breast and bottle feeding to sleep; bottle feeding by liquid type (including expressed breast milk), age of introduction of solids, and an ‘ever consumed’ checklist of foods high in free sugars.

At 1 year of age, in the absence of an appropriate screener or food frequency questionnaire for sugars intakes, a combined 24-hour recall and 2-day food record were used. Data were collected and entered by a small team of nutritionists and dietitians who participated in training and calibration exercises in order to standardise procedures (see 3.2.1, p. 73). For the dietary data collection at 2 years of age, a food frequency questionnaire was developed and assessed for external validity (see 3.3, p. 82). The resulting SMILE-FFQ is an outcome of this thesis, a copy of which is included in Appendix D. The dietary assessment methods employed by

SMILE at 1 and 2 years of age are described in detail in Chapter 3, and the results for free sugars reported in Chapter 4.

Breastfeeding exclusivity was measured, however 'any breastfeeding' was used for the investigation of ECC risk. Due to the small number of children who had never been breastfed, they were grouped with those breastfed for less than 1 month, and classified as 'minimal' breastfeeding. Similarly, as most children had ceased breastfeeding by 2 years of age, breastfeeding beyond 1 year was the highest duration category. As a result, we are not able to investigate the ECC risk from breastfeeding beyond 2 years compared to beyond 1 year.

A range of child and parent oral health behaviours were measured to support the broader SMILE outcomes, including frequency of tooth brushing, toothpaste type and amount, and frequency of dental visits. Additional socio-demographic data were collected at baseline, including household income, smoking status, and mother's country of birth. None of these variables were included in the final models investigating breastfeeding and ECC, as they were highly correlated with IRSAD and maternal education, which were identified *a priori* by Directed Acyclic Graphs as the key confounders.

Dissemination activities aim to reach both nutrition and dental communities, via reporting in Q1 journals and international conferences in both dental, and nutrition and dietetics disciplines.

2.7 Summary

This chapter commenced with a determinant analysis of early childhood caries, introducing a simple interaction between free sugars and cariogenic bacteria that belies a complex disease with wide-ranging determinants. An investigation into whether breastfeeding practices could play a role in the development of ECC followed, describing plausible mechanisms of action, particularly once complementary foods are introduced. The potential role of fluoride as an effect modifier in this relationship was identified, highlighting the National Child Oral Health Study finding that breastfeeding beyond 2 years of age was only associated with increased ECC for children without exposure to fluoridated mains water.

The current evidence base was critiqued, demonstrating the limitations of studies to date, but introducing what appears to be a protective effect of breastfeeding in early life, and a detrimental effect with extended breastfeeding duration and night-time feeding. The challenges in designing studies that adequately measure breastfeeding and other dietary exposures were discussed, and recommendations for how to improve study design quality were provided.

The importance of this issue cannot be understated, as both inadequate breastfeeding and early childhood caries are major global health issues. Inconsistencies in current practice guidelines reflect the confusion surrounding the issue, and highlight the need for clarification.

Therefore, it is necessary to conduct a prospective cohort study, with clear definitions of breastfeeding and early childhood caries, and thorough and validated data collection methods for the outcome, exposure and confounding variables; in order to investigate the relationship between breastfeeding practices and early childhood caries. The Study of Mothers' and Infants' Life Events affecting oral health is well-placed to do this.

Chapter 3 METHODOLOGY FOR ESTIMATING FREE SUGARS INTAKES AT 1 AND 2 YEARS

3.1 Overview

This chapter describes the dietary assessment methods used to estimate free sugars intakes of the SMILE cohort at 1 and 2 years of age.

Section 3.2 discusses the selection of methods employed at each time point, followed by a description of the 1 year dietary data collection methods.

Section 3.3 of this chapter reports on the development and validity testing of the SMILE Food Frequency Questionnaire (SMILE-FFQ), prior to administration to the cohort at 2 years of age. A copy of the SMILE-FFQ is provided in Appendix D. This section is presented by the following paper, which was published in 2017, in the *International Journal of Environmental Research and Public Health* (open access), for the special issue titled *Epidemiology and Determinants of Dental Caries in Children*:

> Devenish, G., Mukhtar, A., Begley, A., Do, L., & Scott, J. (2017). Development and Relative Validity of a Food Frequency Questionnaire to Assess Intakes of Total and Free Sugars in Australian Toddlers. *Int J Environ Res Public Health*, 14(11) doi:10.3390/ijerph14111361

Fluoride was not included in the initial validity testing, as there is no complete, Australian nutrient database for fluoride. The development of a fluoride database and subsequent validity testing of the SMILE-FFQ is reported in 3.4.

The methods of administering the SMILE-FFQ to the SMILE cohort at 2 years of age are described in 3.5, followed by a chapter summary in 3.6.

Results for free sugars intakes of SMILE participants at 1 and 2 years of age are reported in Chapter 4 and included in investigations of infant feeding practices and early childhood caries in Chapter 5.

This chapter addresses the secondary aim of this work, via objective 2, which is to *develop a dietary assessment tool to assess intakes of total and free sugars from major food and beverage sources, fluoride from non-water sources and other key foods relevant to dental caries in Australian toddlers aged 18–30 months via a proxy report* and objective 3, which is to *investigate the relative validity of the tool developed in objective 2, for total sugars, free sugars and fluoride against repeat 24-hour recalls, using external calibration methods* (see Table 1.1, p. 3).

3.2 SMILE Dietary Assessment Methods: Free Sugars

Dietary assessment methods employed by SMILE were the result of a thorough review and design process. An early literature search identified that the main dietary outcome of interest was 'sugars', either added, free or non-milk extrinsic sugars, all with similar but inconsistent definitions (Colak et al., 2013; Evans et al., 2013a; Kelly et al., 2003; Moynihan & Petersen, 2004). During the time of candidature, the World Health Organization (2015) guideline for sugars intakes of adults and children was released, which provided a clear mandate for using the definition of free sugars. Also during this time, the AUSNUT2011–13 national nutrient database was released (FSANZ, 2014), and later, a matching dataset of free and added sugars values that corresponded with AUSNUT2011–13 (FSANZ, 2016). The initially proposed dietary assessment methods were adapted to incorporate these releases.

Issues of subject burden and practicality of administration influenced the selection of a suitable dietary assessment method. With up to 2181 children in the study, dietary assessment methods needed to give the highest quality data, while keeping research costs and subject burden as low as practical. The nutrition research team were based in Perth, and the SMILE cohort in Adelaide, so we were unable to conduct face-to-face dietary interviews, although telephone interviews were possible.
At recruitment, SMILE participants were invited to indicate their preference of online or paper-based questionnaire, or telephone interview, and the dental and socio-demographic questionnaires were available in all three formats, so participants could use their preferred method (Do et al., 2014). It was not possible to conduct the

dietary assessment via three formats, although the 2 year data was administered via the participants' choice of online or paper-based questionnaire.

The dietary data were collected using a 24-hour recall and 2-day estimated food record when each child was 1 year of age, and administration of the SMILE Food Frequency Questionnaire (SMILE-FFQ) at 2 years of age.

3.2.1 Free Sugars at 1 Year of Age

At 1 year of age, it was thought many children would still be making the transition to family foods, with high inter- and intra-subject variation in portion size, plate waste and food variety (Byrne et al., 2014; Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013). There were no validated tools available to capture free sugars at 1 year of age in Australian children, so a direct measurement method such as food record or recall was considered to be the most appropriate. Methods used by the NOURISH and SAIDI studies with a similar age group combined the 24-hour recall with a 2-day food record (Byrne et al., 2014), so SMILE employed a similar technique. These dietary assessment methods used at 1 year of age are described in detail here, and summarised in the first publication (see 4.3.2, p. 120).

3.2.1.1 24-Hour Recall and 2-Day Food Record

A range of techniques were employed to maximise response rate and quality of the dietary data collected. A food record booklet was designed for SMILE, which included detailed instructions for participants, a 1-day example of a completed food record, space to complete the food record and reference food and serving measure images. The images were adapted from those used in the Australian Health Survey (ABS, 2014b), and included pictures of household measures and amorphous food shapes. These booklets were posted to participants after the child's first birthday, with instructions not to complete the food record until a researcher had telephoned them. This call was made approximately 1 week after the materials had been posted, at which time the 24-hour recall was conducted, followed by instructions for completing the food record. Participants received an SMS on the morning of the call so they knew to expect a call and were familiar with the incoming number. They were invited to reply to the SMS with a preferred time for the interview that day (optional).

Two research dietitians were trained to conduct the 24-hour recalls via telephone using the five step multi-pass method (ABS, 2014b). A probing and protocol booklet was designed for the research dietitians to follow, to assist with applying the method to parents of young children. The question about alcohol was removed from the traditional forgotten foods list and the question, “any rusks or teething foods?” was added. The probing protocol ensured a suitable level of detail was obtained for the foods and nutrients of interest, while allowing the research dietitians to be flexible and responsive to the perceived participant burden. A telephone script was included to standardise the call and ensure consistent and correct instructions for completing the food record were provided. A copy of this probing and protocol booklet is provided in Appendix E.

During the recall, the research dietitian referred the participant to the food record booklet that they had received by post, using the reference food images to assist with estimating portion size. This also allowed the researcher to train the participant in the use of the reference images, and set expectations around the level of detail required in the subsequent food record. Once the 24-hour recall was completed, the research dietitian used a lookup table of pre-assigned days to allocate 2 days on which to complete the food record. This table ensured equal representation across the days over the whole cohort, and that each individuals’ allocated days included one weekend day and one other non-consecutive week day that fell within the 10 days that followed the phone call. The researcher then gave instructions for completing the food record, and answered any participant questions.

A reply paid envelope was provided for the return of the food record, and participants who had completed the 24-hour recall interview were sent weekly SMS reminders to complete and return the food record, commencing 2 weeks after the 24-hour recall. If no record had been received after a further 4 weeks, the research dietitian that conducted the 24-hour recall phoned, or attempted to phone, the participant to encourage them to return the food record.

3.2.1.2 Database Preparation

The current national nutrient database, AUSNUT2011–13 (FSANZ, 2014) was used to analyse response data. As the database was developed for the 2011–13 Australian Health Survey, it focused on foods consumed in those years by Australians aged 2 years and older (FSANZ, 2014). The database contains only a small number of commercial infant foods, which does not represent the food supply experienced by the infants and toddlers in our cohort.

Before entering the data, an infant foods database was compiled from a food list produced for the SMILE-FFQ validation study (see 3.3),and an infant product list produced during a supermarket audit earlier in the year (Lim et al., 2015), supplemented by the manual collection of nutrition information for infant products that were new to the market. This database included 187 foods, based on information from nutrition panels and manufacturer websites. Each item was mapped to a comparable product in AUSNUT2011–13 to provide missing micronutrient values, and assigned an 8-digit code following the AUSNUT2011–13 naming conventions.

The Louie et al. (2015) methodology for estimating the added sugar content of foods was adapted to match the WHO (2015) definition of free sugars, and then used to assign a free sugars value to each new infant food product. Food Standards Australia and New Zealand [FSANZ] (2016) report that this same method was followed in the development of the free sugars database to correspond with AUSNUT2011–13, although the details of how the Louie et al. (2015) method was adapted were not available. Table 3.1 shows how the 10 steps of the method were adapted to estimate free sugars for the infant foods list in SMILE.

A list of the 187 infant foods and their estimated added and free sugars values is provided in Appendix F.

Table 3.1 Revised method for estimating free sugars

Method Step	Louie et al. (2015) method for estimating added sugars	Revised method for estimating free sugars
Step 1	Assign 0 g added sugar to foods with 0 g total sugars	as per Louie, terminology change added to free sugars
Step 2	Assign 0 g added sugar to foods in the following food groups: (a) 100% Fruit/vegetable juice and juice/cordial base sweetened with artificial sweeteners only (b) All spices and herbs (c) All fats and oils (d) All plain cereal grains, pastas, rice and flours (e) Eggs and egg products (except egg-based desserts) (f) Fresh fruit, fresh vegetables (including salads with no dressing), fresh meat, fresh seafood and tofu (g) Fruits canned in 100% fruit juice or liquid sweetened with artificial sweeteners only (h) Intensely sweetened jam and beverage base (without added sugar) (i) Legumes (fresh, dried and/or processed, except sweetened varieties) (j) Mixed meat dishes with no added sugar (decided on the basis of ingredient information; e.g., recipe) (k) Non-sweetened alcoholic beverages (l) Non-sweetened coffees and tea (m) Non-sugar-sweetened milk and buttermilk; breast milk (n) Non-sugar-sweetened dairy products (including yoghurts sweetened with artificial sweeteners only) (o) Nuts (except sweetened varieties and nut bars), coconut (and products except sweetened varieties) and seeds (p) Oats (and porridge) with no added sugar (decided based on ingredient information; e.g., ingredient list) (q) Plain pastries without filling (such as chocolate, dried fruit and/or nuts) (r) Plain breads (except gluten-free), English muffin, bagels, pizza bases and naan (s) Unsweetened dried fruits	Assign 0 g free sugars to foods in the following food groups: (a) 100% vegetable juice (c)-(f) as per Louie method [(g) removed from step 2] (h) Intensely sweetened beverage base (without added sugar or fruit) (i)-(m) as per Louie method (n) Non-sugar-sweetened dairy products with no added fruit (including fruit-free yoghurts sweetened with artificial sweeteners only) (o)-(s) as per Louie method
Step 3	Assign 100% of total sugars as added sugar for foods in the following food groups: (a) All confectionery except those containing dairy products such as fudge and chocolate (b) Breakfast cereals and cereal bars without fruits, chocolate, dairy or milk solids (c) Coffee and beverage base with no milk solids, dry or made up with water (d) Crumbed/battered meat and seafood (e) Processed meats (f) Regular soft drinks, sport drinks, flavoured water and non-fruit-based energy drink (g) Savoury biscuits, sweet biscuits, cakes and buns, donuts and batter based products that do not contain fruit, chocolate or dairy products (h) Soy beverages and soy yoghurt without added fruits (i) Stock powder (j) Sugar and syrups	Assign 100% of total sugars as free sugars for foods in the following food groups: (a)-(e) as per Louie method (f) Regular soft drinks, sport drinks, flavoured water and energy drink (g)-(j) as per Louie method List addition: (k) All fruit juice and cordial base
Step 4	Where added sugar contents of ALL ingredients in the product are known; calculate based on the proportioning method	as per Louie, terminology change added to free sugars
Step 5	Where a comparable unsweetened variety is available; calculate by comparison with values from the unsweetened variety	Where a comparable variety is available and the product does not contain fruit; as per Louie
Step 6	Where analytical data of individual sugar types are available: If analytical data for lactose are available, and the ingredients do not include dried fruits or malted cereals, added sugar content is calculated as total sugars − lactose. If the food contains malted cereals and lactose and maltose data are available, added sugar content is calculated as total sugars − lactose − maltose	as per Louie, terminology change added to free sugars
Step 7	Where similar products with known added sugar are available (from overseas database or steps 1-6): Borrow value from similar foods	as per Louie, terminology change added to free sugars
Step 8	Where possible: Subjectively estimate added sugars on the basis of ingredients and/or common recipes	as per Louie, terminology change added to free sugars
Step 9	Where the added sugar contents of ingredients in the product are known after steps 5-8; calculate based on the proportioning method	as per Louie, terminology change added to free sugars
Step 10	50% of the total sugars as added sugars	as per Louie, terminology change added to free sugars

3.2.1.3 Data Entry

The data were entered into FoodWorks version 8 (Xyris Software, 2012–2017, Brisbane, Australia), using the AUSNUT2011–13 national nutrient database (FSANZ, 2014). Free sugars values were not in the original database, but were made available later (FSANZ, 2016). These were imputed in Microsoft Access version 15 (Microsoft Corporation, 2013, Washington, DC, USA) after data entry was complete.

The 3 days of data were double-entered. The first entry phase was conducted by a trained team of four nutritionists enrolled in the Masters of Dietetics at Curtin University. A data entry protocol was designed, detailing standard selections for common foods, methods for determining portion sizes from household measures, and strategies for dealing with insufficient detail. The nutritionists were trained by the candidate (GD) in the application of the protocol, using an example of the data entry and decision-making process, followed by a discussion of other scenarios. The four nutritionists and the candidate each entered the 24-hour recall and 2-day food record for the same five participants (arbitrarily selected), and compared nutrient outputs and foods entered. The protocols were revised and updated to reflect the outcome of discussions. During the data entry phase, the four nutritionists discussed uncertainties with one another, appending the protocols and raising issues with the candidate as needed.

The 24-hour recall was used as a reference tool for the food record, whenever detail was missing. The 24-hour recall often included additional information regarding products used in the household as a result of probing questions during the interview. For example, where a participant wrote only “milk” in the record, the choice of full cream, hi-lo, skim, A2 etc. could be determined by the 24-hour recall, and when a food record only stated “margarine”, the brand and type listed in the 24-hour recall could be used. If the 24-hour recall and food record included specifics that differed, these were entered according to what was stated for each day.

Intake of breast milk was reported in minutes, and converted to a volumetric amount at a rate of 10 grams per minute to a maximum of 100 grams per feed (Lennox et al., 2013). Breastfeeds of less than 2 minutes duration were not included, as they were not considered long enough to contribute to nutrient intake (Hornell et al., 1999;

Kent et al., 2006). If a second breastfeed commenced within 30 minutes of the start of the previous feed it was not considered a new feed, and so the two breastfeeding durations were summed, to a maximum of 10 minutes.

The protocol for managing incomplete dietary data is described in 3.2.1.4. Any food records that were illegible, missing substantial detail, or with missing or incomplete data were referred to the supervising team (GD, JS), who made the final decisions about exclusion.

After initial entry, descriptive statistics were used to identify outliers for the weight of food and energy consumed. The data for these participants were checked for entry errors in FoodWorks by the trained nutritionist who initially entered the data, and if no error was found, it was re-checked by the candidate.

The second entry phase was conducted by the candidate and a student dietitian on a Curtin University summer research scholarship. After training and calibration against the same 5 records entered for the first data entry phase, the student dietitian entered the 24-hour recalls from participants who completed the recall but did not post back a food record (n = 328). During this time, the candidate also entered five of these 24-hour recalls (randomly selected), and then compared nutrient outputs and foods entered, discussing discrepancies with the student dietitian. Once this work was completed, data for all participants with 3 days of dietary data were re-entered by the candidate and the student dietitian, using a copy of the FoodWorks data entered in the first phase, and overriding food items or amounts where appropriate. After the second entry phase, descriptive statistics were again used to identify outliers for the weight of food and energy consumed, and the food records checked for entry errors.

3.2.1.4 Incomplete Dietary Data at 1 Year of Age

Methods for handling incomplete dietary data vary, and are scarcely reported in the literature. The use of a protocol for data entry and cleaning ensures that decisions are made and applied consistently (Kerr et al., 2013). For SMILE, protocols were created for each phase of data collection, entry, cleaning and analysis at every data collection time point, and included methods for handling partially completed responses.

Incomplete responses in the 1 year dietary questionnaire were managed based on completeness of each day, and the provision of 3 days of data. There were 7 food records that could not be entered due to insufficient detail or illegible information provided. In addition, some food diaries that were returned appeared to have part of a day missing. As it was not possible to determine whether reported food intakes that day were truly complete, all food record entries that recorded for more than half the day (eg from waking until after a mid-day meal or from mid-morning into the evening) were included as a complete day. The use of the Multiple Source Method to adjust for day to day variation (see 3.2.1.5), and the exclusion of participants with implausible intakes (see 4.2.1, p. 114) also helped to ameliorate the impact of incomplete dietary data.

Only those with 3 days of complete dietary data were included in the descriptive dietary analysis (3.3 and 3.4). There were 328 participants who completed the 24-hour recall interview but did not return the food record, 7 who returned a food record but did not complete the 24-hour recall interview, and 5 who completed the 24-hour recall but returned a food record containing only one complete day of data. These participants were retained in the analysis population for the SMILE outcome analyses (Chapter 5), after internal validity testing showed that the 24-hour recall alone had acceptable agreement with the 3 days of dietary data, for intakes of energy, protein, calcium, iron, and added sugars (Beaton et al., 2018). Conversely, 10 participants did not complete the 24-hour recall but posted back a detailed 3-day food record, and so these were included in both the dietary and SMILE outcome analyses. A participant flow diagram for the 1 year dietary data is provided in Chapter 4 (Figure 4.1, p. 125).

3.2.1.5 Estimating Usual Intake of Free Sugars as a Percentage of Energy

Until recently, the reporting of dietary intake via an average of several days of data has been the norm, however there is no consensus on the number of days needed to produce a reliable average value (Thompson & Subar, 2013). It is likely that the minimum number of days differs by participant characteristics and nutrient or food groups of interest, as well as dietary assessment method used (Willett, 2013). Averaging an insufficient number of days is likely to result in a distribution of intakes that is wider than actual usual intakes, due to the large day-to-day variation in the diets of individuals (Thompson & Subar, 2013).

The Multiple Source Method (MSM) is a statistical modelling method that uses two or more short-term measurements to estimate usual intake of foods or nutrients (Harttig et al., 2011). The MSM was developed within the European Food Consumption and Validation Project, and is freely available via a web-based application. This was applied to the 24-hour recall and each day of the 2-day food record to estimate usual intakes of total sugars, free sugars and energy at 1 year.

The percentage of energy from free sugars was then calculated for comparison with the WHO (2015) guideline, using the energy value for sugars of 16.7 kilojoules per gram (FAO, 2003). The equation is as follows:

$$\%EnergyFreeSugars = [(FreeSugars\_g \times 16.7) \div Energy\_kJ] \times 100$$

Where *%EnergyFreeSugars* refers to the percentage of energy from free sugars, *FreeSugars_g* refers to usual free sugars intakes in grams, and *Energy_kJ* is usual energy intake in kilojoules as determined by the MSM.

3.2.2 Free Sugars at 2 Years of Age

At 2 years of age, a Food Frequency Questionnaire (FFQ) was selected as the most appropriate method, due to its suitability for large, prospective studies (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). Once developed, it is quicker and cheaper to administer than a 24-hour recall or food record, and response data can be entered by researchers without specialist nutrition training. The questionnaire can be self-administered and is thought to have a lower subject burden than food records (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). It is well-suited for administration to a large cohort.

Although it is a commonly used method, the FFQ must be tailored to both the population and outcomes of interest if it is to produce meaningful data (NIH & NCI, 2018). Initially, it was hoped that an existing FFQ could be used with a calibration study, however upon investigation there was no questionnaire that had been validated for free sugars in Australian toddlers, nor was there a comparable tool that could be modified for this population. The SMILE-FFQ was developed to address this.

The SMILE-FFQ was designed to assess intakes of total and free sugars from major food and beverage sources, along with fluoride and key foods relevant to dental caries in Australian toddlers aged 18–30 months via a proxy report. A copy of the SMILE-FFQ is provided in Appendix D. The SMILE-FFQ was developed following the methods described by Willett (2013) and Coulston et al. (2013). A broad approach was used to create the initial food list, including generating a database of all foods containing sugars or fluoride in the NUTTAB 2010 food composition database (FSANZ, 2011b), and expanding it to include known carioprotective foods identified in the literature (Moynihan & Petersen, 2004). Data reduction methods transformed this large list into an 89 line-item questionnaire. These methods are further described in 3.3.2.

The SMILE-FFQ was assessed for relative validity and reproducibility for total and free sugars against repeat 24-hour recalls, in an external population of Australian toddlers (who were not participants in SMILE). These findings are reported via publication in 3.3, with additional fluoride validity testing (unpublished) in 3.4. The ethics approval notice for this study is provided in Appendix B (Curtin University Human Research Ethics Committee approval number #SPH-39-2014, approval date: 19 Jun 2014). Administration of the SMILE-FFQ to the SMILE cohort at 2 years is further described in 3.5, and reported via publication in Chapter 4 (see 4.4, p. 140).

3.3 Original Article: Development and Relative Validity of a Food Frequency Questionnaire to Assess Intakes of Total and Free Sugars in Australian Toddlers

Abstract: *Background:* Dental research into early childhood caries is hindered by a lack of suitable dietary assessment tools that have been developed and validated for the population and outcomes of interest. The aim of this study was to develop and investigate the relative validity and reproducibility of the Study of Mothers' and Infants' Life Events Food Frequency Questionnaire (SMILE-FFQ), to assess the total and free sugars intakes of Australian toddlers. *Methods:* The SMILE-FFQ was designed to capture the leading dietary contributors to dental caries risk in toddlers aged 18–30 months via a proxy report. Ninety-five parents of Australian toddlers completed the questionnaire online before and after providing three 24-h recalls (24HR), collected on non-consecutive days using the multipass method. Total and free sugars were compared between the two SMILE-FFQ administrations and between each SMILE-FFQ and the 24HR using multiple statistical tests and standardised validity criteria. Correlation (Pearson), mean difference (Wilcoxon rank test) and Bland Altman analyses were conducted to compare absolute values, with cross-classification (Chi-Square and Weighted Kappa) used to compare agreement across tertiles. *Results:* All reproducibility tests showed good agreement except weighted kappa, which showed acceptable agreement. Relative validity tests revealed a mix of good and acceptable agreement, with total sugars performing better at the individual level than free sugars. Compared to the 24HR, the SMILE-FFQ tended to underestimate absolute values at lower levels and overestimate them at higher levels. *Conclusions:* The combined findings of the various tests indicate that the SMILE-FFQ performs comparably to the 24HR for assessing both total and free sugars among individuals, is most effective for ranking participants rather than determining absolute intakes, and is therefore suitable for use in observational studies of Australian toddlers.

Keywords: food frequency questionnaire; dietary assessment; validation; early childhood caries; pre-school; sugar; free sugars.

3.3.1 Introduction

Dental diseases are the most prevalent non-communicable disease globally (WHO, 2015) and the leading cause of preventable hospitalisations among children in Australia (AIHW, 2012). The prevalence of dental caries in Australian children began to decline significantly during the 1970s. However, in the mid-1990s, this downward trend reversed and caries prevalence has increased steadily ever since (Armfield & Spencer, 2008; AIHW, 2015). In addition, disparities in caries experience exist between children based on socio-economic status, remoteness and availability of fluoridated water (Armfield & Spencer, 2008).

The relationship between free sugars intakes and dental caries is well established, although the lower level of no effect is less clear (Moynihan & Petersen, 2004; Moynihan & Kelly, 2014; Sheiham & James, 2014; WHO, 2015). In 2015, the World Health Organization released the Guideline: Sugars intake for adults and children, with a focus on preventing dental disease and obesity (WHO, 2015). Although the Guideline sets out a strong recommendation to reduce the intake of free sugars to less than 10% of total energy intake, the conditional recommendation to further reduce intake to less than 5% of total energy was limited by the low quality of evidence. The supporting evidence review highlights the lack of consistency and precision of dietary assessment methods in dental studies (Moynihan & Kelly, 2014), leading to a call within the Guideline for new studies with an improved dietary assessment methodology (WHO, 2015).

Controlling for key dietary risk factors is a critical component of oral health research. However, dietary assessment is complex, and reviews of dental studies highlight the inconsistency and imprecision of approaches used for measuring dietary intakes and food behaviours (Harris et al., 2004; Moynihan & Petersen, 2004; Valaitis et al., 2000). Newly designed dietary assessment tools should be validated prior to use, and existing tools should be calibrated to each cohort (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). An ongoing limitation of dental research is the lack of rigour in dietary assessment methodology, with many studies still not using validated dietary questionnaires to capture sugars intake, and fewer still undertaking internal calibration (Harris et al., 2004; Moynihan & Kelly, 2014).

One reason for this lack of rigour is that often an appropriate tool does not exist (Evans et al., 2013b; Harris et al., 2004). Dietary assessment design and validation is a branch of nutrition research, and dental research teams do not always have the resources or nutrition expertise required to undertake validity studies. Childhood dietary intake is particularly challenging to capture, due to the participant age and varying ability to self-report intake, as well as the greater rate of fluctuation in dietary intake patterns throughout childhood compared to adults (Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013). This is especially relevant throughout the first three years of life, as a child progresses from a newborn diet of breast milk or infant formula, via a range of textures, through to family foods. This transitioning diet combined with the unique dietary data requisites of dental research means that the tools used during the pre-school years need to be age-specific and developed purposely for dental research.

There are a number of methods used in dietary assessment, but the Food Frequency Questionnaire (FFQ) is considered the most appropriate data collection method for large, prospective studies (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). Once developed, it is quick and inexpensive to administer and process, as it can be self-administered and rapidly analysed. Additionally, it has a lower subject burden than weighed food records, and captures usual dietary intakes over a longer period of time (Thompson & Subar, 2013; Willett, 2013). Although it is a commonly used method, the FFQ must be tailored to both the population and outcomes of interest if it is to produce useful data (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013).

The aim of this study is twofold: firstly, to develop a FFQ to assess intakes of total and free sugars from major food and beverage sources, fluoride from non-water sources and other key foods relevant to dental caries in Australian toddlers aged 18 – 30 months via a proxy report. Secondly, to investigate the relative validity and reproducibility of this FFQ for total and free sugars against repeat 24-hour recalls (24HR).

3.3.2 Materials and Methods

Study of Mothers' and Infants' Life Events affecting oral health

The Study of Mothers' and Infants' Life Events affecting oral health (SMILE) is a longitudinal birth cohort study that aims to identify and evaluate the relative importance and timing of critical factors that shape the oral health of young children and then evaluate those factors in terms of their interrelationship with socio-economic influences (Do et al., 2014). A limited number of dietary assessment tools have been used to assess young children's total dietary intake (Australian Institute of Health and Welfare, 2011; Daniels et al., 2009; Scott et al., 1997; Scott et al., 2006b); however, a tool for the dietary assessment of dental significance through the toddler years was not available. As such, a FFQ was designed to capture the leading dietary contributors to dental caries risk in toddlers aged 18–30 months via a proxy report for use in SMILE.

SMILE food frequency questionnaire development

Development of the SMILE-FFQ occurred in four stages, following the methods described by Willett (2013) and Coulston et al. (2013). Firstly, a brief review of the literature identified the leading dietary contributors to dental caries risk, namely major food and beverage sources of total sugars, free sugars and fluoride, as well as protective foods including cheese and other milk products, chewing gum and xylitol (Moynihan & Petersen, 2004). The World Health Organization (2015) definition of free sugars was used, which includes "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".

Secondly, a food list was generated, incorporating all foods that would provide these dietary contributors. This list was then refined to exclude food items that:
(a) contained only a small amount of the nutrient in question (for example, commercial pasta sauce containing approx. 5% total sugars); or (b) are not typically consumed by individuals within this age group (for example, chewing gum, alcohol, coffee, and energy drinks). During this process, foods were collapsed into line-items based on similarity of the food and of total and free sugars content and then grouped into blocks by food type. The final list (Supplementary Materials) consisted of

24 question blocks containing 89 line-items. Four additional questions were added to further split the coding of some food items (for example, "If your child eats yoghurt, do you choose reduced fat versions?") and two questions were included to capture eating behaviours of dental significance (usual drinking vessels and typical number of eating occasions per day).

Thirdly, frequency and quantity response options appropriate to this age group were developed for each line-item. Seven frequency response options were used for all line-items, commencing with "never or rarely" before ranging from "1 time every 2 weeks" to "3 or more times per day". Quantity response options were tailored to each question block, using a combination of household measures (teaspoon, tablespoon, cup) and typical portion sizes (piece, tub, pouch, etc.). Weight (g) or volume (ml) was also provided, except in blocks which only used teaspoon and tablespoon options, such as condiments.

Finally, a database was developed to analyse the SMILE-FFQ, linking scoring algorithms for all possible responses to nutrient values for total and free sugars, derived from representative foods in the AUSNUT2011–13 food composition database (FSANZ, 2014).

The SMILE-FFQ was produced online using Qualtrics software, 2014 version (Qualtrics, Utah, USA, www.qualtrics.com). A copy of the questionnaire is provided in Supplementary Materials (Appendix D).

Food Frequency Questionnaire Validation

Curtin University Human Research Ethics Committee approved the study (Approval No. SPH-39-2014). The validation study was registered with the US National Cancer Institute Dietary Assessment Calibration/Validation Register (Study ID 0293).

Participants and recruitment

Inclusion criteria were parents with a child aged between 18 and 30 months at the time of recruitment, who lived in Australia and who had access to the internet, an email address, and telephone. No other inclusion or exclusion criteria were identified at this stage; however, one parent later withdrew from the study as they were unable to report their child's dietary intake on any weekday.

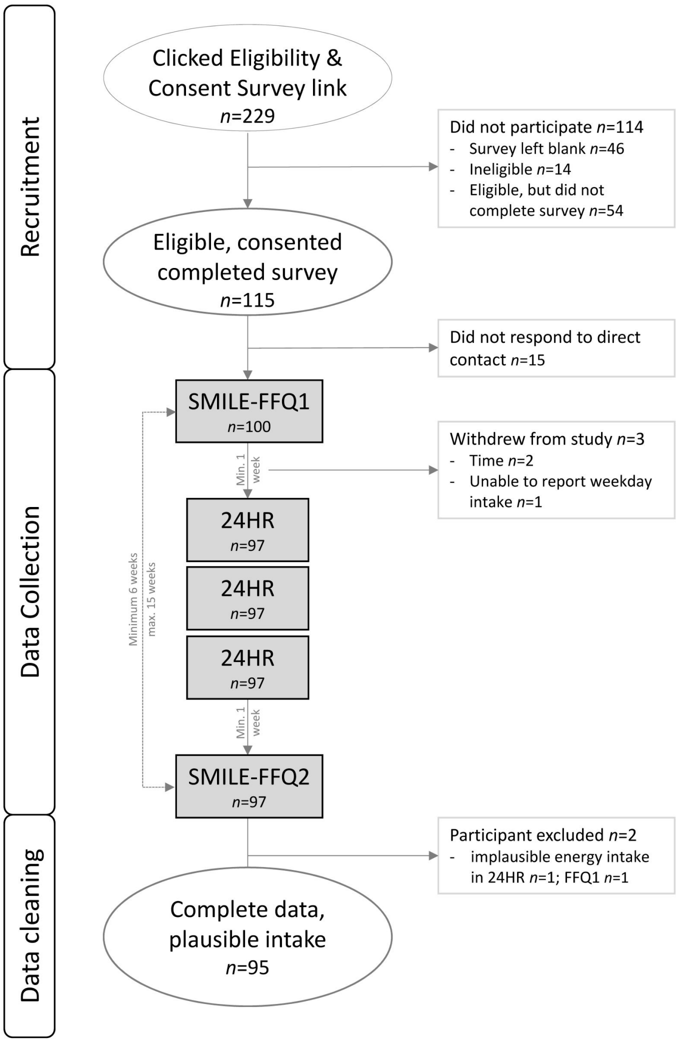
A Facebook page was created to recruit participants, with a target sample size of 100, in line with recommendations by Willett (2013) and comparable to similar studies (Andersen et al., 2004; Flood et al., 2013; Marriott et al., 2009; Watson et al., 2015). The page included study information and a post with a link to an expression of interest, eligibility, and consent survey. The first page of the survey asked participants to report against the inclusion criteria. Those not meeting the eligibility requirements were diverted to an exit page, while eligible participants continued to the consent section. The survey was closed two weeks after the page launched, with a reach of 1753 people who saw the post, 229 who clicked the link, and 115 eligible participants who completed the survey (Figure 3.1). Fifteen people who completed the eligibility survey did not respond to any follow up communication or questionnaires, so the final number recruited was 100. Three participants withdrew after the first questionnaire, and the remaining 97 completed the study.

Data collection

After recruitment, participants were entered into the study in three waves between August and October, to allow a single researcher to conduct all telephone diet recalls. Participants that were in the second or third wave were informed of the delay and the expected date of commencement. Data collection for all participants occurred between August and December, with one participant's final FFQ completed in early January (the greatest duration from commencement at a total of 15 weeks).

Data collection, depicted in Figure 3.1, occurred over a minimum six-week period for each participant. Parents were sent a link to the online questionnaire (SMILE-FFQ1) and followed-up via weekly reminder emails which contained an unsubscribe option. One week after SMILE-FFQ1 was completed, participants entered the 24-h diet recall phase (24HR), consisting of three recalls conducted via telephone on non-consecutive days by the principal researcher (GD) who is a dietitian. A random number generator was used to allocate three days within a four week period for the participant recalls; two weekdays and one weekend day. On the day of a recall, participants were sent an SMS to inform them they would be receiving a call and were able to nominate a suitable time of day for the call. If the child had been unwell or the parent was unaware of intake on the previous day (e.g., child in childcare), the recall was not conducted, and a new day was randomly allocated. If the parent was able to report intake despite the child being in the care of others, the allocated recall day was retained. The five-step multipass method (Australian Bureau of Statistics, 2014b) was used to conduct the 24HR, using a modified forgotten foods list (the question about alcohol was substituted for “any rusks or teething foods?”) and a uniquely designed probing protocol with specific questions for toddler foods in the detail cycle phase. One week after the final 24HR, and at least six weeks after SMILE-FFQ1, participants were sent a new link to the online questionnaire (SMILE-FFQ2). Demographic data were collected on the final page of the SMILE-FFQ2, with the child’s date of birth also captured in the eligibility survey.

Figure 3.1 Recruitment and data collection for the SMILE-FFQ validation study



SMILE-FFQ: Study of Mothers’ and Infants’ Life Events Food Frequency Questionnaire; 24HR: 24-hour recalls.

The 24HR were entered into FoodWorks version 8 (Xyris Software, 2012–2017, Brisbane, Australia) using the current Australian food composition database, AUSNUT2011–13. As FoodWorks does not provide free sugars values, these were imputed in Microsoft Access version 15 (Microsoft Corporation, 2013, Washington, DC, USA) using a dataset developed to accompany AUSNUT2011–13. This dataset was developed by Food Standards Australia and New Zealand (FSANZ) using the methodology by Louie et al. (2015), which employed the WHO (2015) definition of free sugars. Mean daily intakes for total and free sugars were obtained for each participant. Descriptive statistics were used to identify outliers for the weight of food and energy consumed and the data were checked for entry errors and resolved.

The survey responses for the SMILE-FFQs were exported from Qualtrics in Excel format and linked to the scoring database using Microsoft Access. Mean SMILE-FFQ1 and SMILE-FFQ2 daily intakes of total and free sugars were then generated for each participant.

Two participants were identified as reporting implausibly high intakes of both energy and total sugars and were excluded from the analysis. Implausible intake was defined as values greater than 3 standard deviations above the mean for both nutrients in at least one questionnaire (Atkins et al., 2016).

Data analysis

Data were exported from Microsoft Access to Microsoft Excel and then analysed using SPSS version 24 (IBM SPSS Statistics for Windows, New York, NY, USA). The data were not normally distributed, so natural log transformation was performed and used with all but the Bland Altman analyses. The data were not energy adjusted, as the SMILE-FFQ was not designed to assess total diet and therefore total energy intakes could not be obtained.

As recommended by Lombard et al. (2015), multiple statistical tests were employed to assess different facets of validity at both the group and individual level. Correlation (Pearson) and Cross-classification (Chi-Square and Weighted Kappa) assessed validity at the individual level. Comparison of means (Wilcoxon rank test) compared agreement between the two tools at a group level. Bland-Altman analyses of the raw data, including calculation of the Limits of Agreement and Bland Altman

Index, investigated individual differences from the group mean and the extent of bias at a group level. Linear regression analysis was undertaken to investigate whether the slope of mean bias was significantly different from zero, indicating proportional bias.

Outcome cut-offs were determined using criteria described in Lombard et al. (2015). For correlation coefficient (Pearson), good agreement was ≥ 0.50, acceptable from 0.20 to 0.49, and poor < 0.20 (Lombard et al., 2015; Masson et al., 2003). For cross-classification (Chi-Square), good agreement was when ≥ 50% of participants were similarly classified (same tertile) and ≤ 10% dissimilarly classified (opposite tertile); and poor agreement was when < 50% were similarly classified and/or > 10% dissimilarly classified (Lombard et al., 2015; Masson et al., 2003). For the Weighted Kappa, good agreement was ≥ 0.61, acceptable from 0.20 to 0.60, and poor < 0.20 (Lombard et al., 2015; Masson et al., 2003). For comparison of means (Wilcoxon), good agreement was at $p > 0.05$ and poor was $p \leq 0.05$. A Bland Altman Index score of ≤ 5% was considered good agreement (Bland & Altman, 1986, 1999).

3.3.3 Results

Participant Characteristics

Data from 95 participants were analysed. Respondents were predominantly university-educated mothers, with a mean age of 34.2 ± 4.4 years at the time of the study (Table 3.2).

Table 3.2 Demographic characteristics of study participants (n = 95)

Characteristics	Mean (SD)
Age of mother (years)	34.2 (± 4.4)
Age of child (months)	25.0 (± 4.1)
Gender of child: female	43.2 %
Mother’s education: completed university	70.6 %

Total and Free Sugars Intakes

Table 3.3 provides mean values of total and free sugars in grams per day as measured by the SMILE-FFQ1, SMILE-FFQ2, and 24HR, along with further descriptive statistics and measures of normality before and after log transformation. SMILE-FFQ1 recorded the highest mean intake and the widest range of responses for both total and free sugars.

Table 3.3 Total and free sugars as measured by SMILE-FFQ1[a], SMILE-FFQ2, and repeat 24-hour recalls

Method	Mean ± SD	Median	Range	Percentile		Normality			
						Raw		Transformed [b]	
				25th	75th	Skew	K-S [c] *p*	Skew	K-S [c] *p*
Total Sugars:									
FFQ1 (g)	74.8 ± 30.8	66.5	18.9–149.7	51.2	96.3	0.57	0.001	−0.41	0.200
FFQ2 (g)	68.7 ± 28.6	65.2	22.6–148.3	49.1	83.6	0.90	0.018	−0.13	0.200
24HR (g)	65.9 ± 19.3	64.8	30.0–130.4	52.2	79.0	0.72	0.200	−0.11	0.200
Free Sugars:									
FFQ1 (g)	22.0 ± 15.5	19.0	1.0–75.6	11.1	26.9	1.31	0.000	−0.63	0.160
FFQ2 (g)	21.3 ± 15.0	18.1	1.0–71.8	10.2	29.2	1.26	0.009	−0.93	0.004
24HR (g)	18.3 ± 9.7	17.3	2.1–58.7	10.9	24.9	1.05	0.036	−0.72	0.091

FFQ: Food Frequency Questionnaire; 24HR: 24-hour recalls.
[a] FFQ 1 and 2 refers to the same tool (SMILE-FFQ) administered before (FFQ1) and after (FFQ2) the recalls.
[b] Natural Log Transformation.
[c] Kolmogorov-Smirnov test for normality.

Relative Validity of the SMILE-FFQ

Relative validity was assessed by comparing total and free sugars values obtained by 24HR to those determined by SMILE-FFQ1 and SMILE-FFQ2. Agreement at the individual level (Table 3.4) was either good (Chi-Square, Pearson for total sugars) or acceptable (Weighted Kappa, Pearson for free sugars). Cross-classifications demonstrated good agreement between the two methods in classifying participants into tertiles, with less than 10% of participants misclassified into an opposite tertile for all methods except free sugars SMILE-FFQ2, which was just over at 10.6%.

Table 3.4 Relative validity of the SMILE-FFQ[a] compared with repeat 24-hour recalls

		Correlation	Cross-Classification			
			Chi-Square [c]			
		Pearson [b]	Similarly Classified (%)	Adjacently Classified (%)	Dissimilarly Classified (%)	κ_w [d]
Total Sugars:	**FFQ1**	0.532 **	54.7	35.8	9.5	0.387
	FFQ2	0.642 **	55.8	40.0	4.2	0.454
Free Sugars:	**FFQ1**	0.392 **	52.6	37.9	9.5	0.359
	FFQ2	0.484 **	50.4	38.9	10.6	0.320

[a] FFQ 1 and 2 refers to the same tool (SMILE-FFQ) administered before (FFQ1) and after (FFQ2) the recalls.
[b] Outcome criteria correlation coefficient (Pearson): Good: ≥ 0.50; Acceptable: 0.20 – 0.49; Poor: < 0.20.
[c] Outcome criteria cross-classification (Chi Square): Good: ≥ 50% similarly classified and ≤ 10% dissimilarly classified; poor < 50% similarly classified and > 10% dissimilarly classified.
[d] Outcome criteria Weighted Kappa: good ≥ 0.61; acceptable 0.20 – 0.6; poor < 0.20.
** $p < 0.01$.

Comparison at the group level (nonparametric) found no significant difference in mean intake between each pair of methods, except for the difference in the mean intake of total sugars between SMILE-FFQ1 and 24HR (Table 3.5).

Table 3.5 Bland Altman statistics for the SMILE-FFQ[a] compared with repeat 24-hour recalls

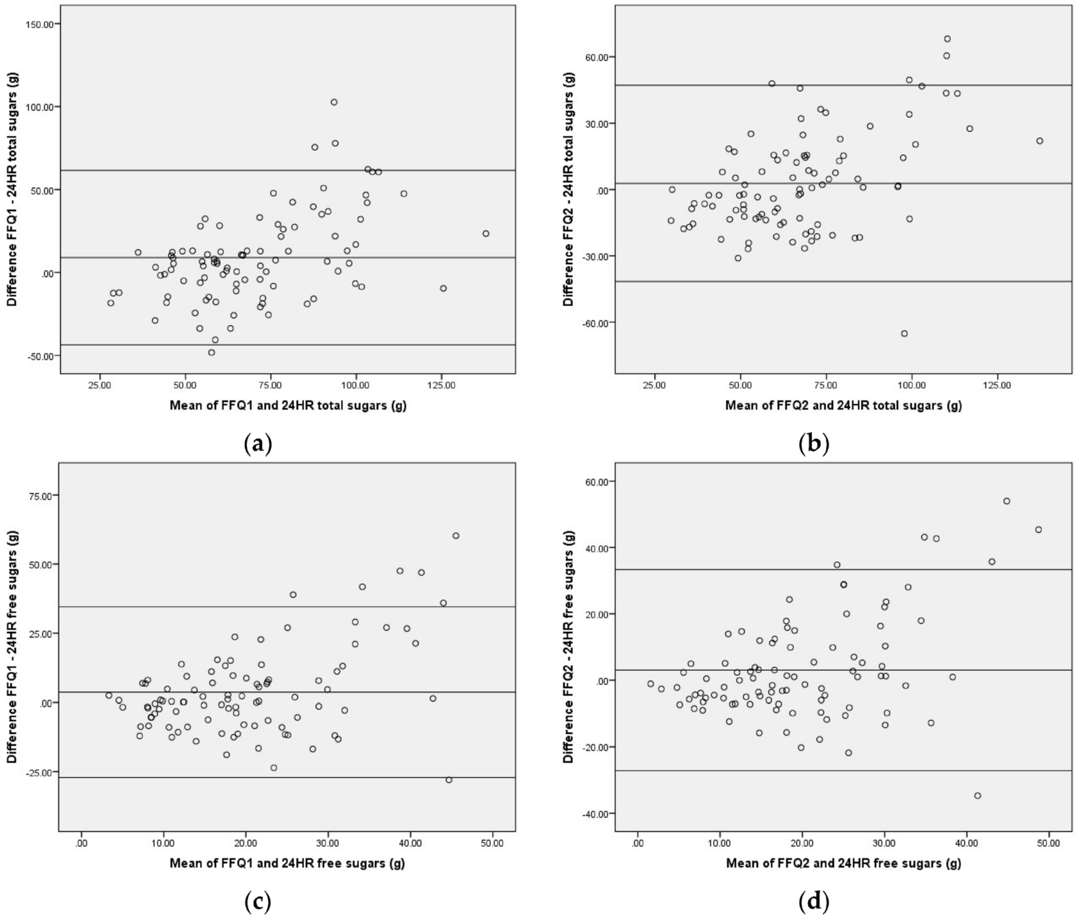
Method	Mean Difference ±SD (g)	Agreement *p* Value [b]	Limits of Agreement (g)	Bland-Altman Index [c] (%)
Total Sugars: FFQ1	8.9 ± 26.8	0.008	−43.7, 61.4	5.3
FFQ2	2.8 ± 22.6	0.596	−41.6, 47.2	5.3
Free Sugars: FFQ1	3.7 ± 15.7	0.180	−27.1, 34.5	7.4
FFQ2	3.1 ± 15.4	0.490	−27.2, 33.3	7.4

[a] FFQ 1 and 2 refers to the same tool (SMILE-FFQ) administered before (FFQ1) and after (FFQ2) the recalls.
[b] Outcome criteria nonparametric agreement (Wilcoxon): Good: $p > 0.05$; Poor: $p \leq 0.05$.
[c] Bland Altman index % of persons outside of limits of agreement. Values ≤ 5% indicate good agreement.

The Bland Altman Index showed either 5.3% or 7.4% of participants falling outside of the limits of agreement, with total sugars close to the acceptable cut-off of 5%. The limits of agreement appear to be wide when compared to the mean, SD, and range of reported intakes (Table 3.3), and were greatest for total sugars between SMILE-FFQ1 and 24HR.

Visual inspection of Bland-Altman plots suggested a positive slope and a tendency to increase in variability as the magnitude of the measure increases (Figure 3.2). Linear regression verified that the slope of bias was significantly different from zero for all four measures ($p < 0.001$), indicating that proportional bias was present. These results suggest that agreement between the SMILE-FFQ and 24HR was better amongst participants with moderate total and free sugars intakes, but the SMILE-FFQ tended to underestimate sugars for participants with lower reported 24HR intakes and overestimate sugars for participants with higher 24HR intakes.

Figure 3.2 Bland Altman plots comparing total and free sugars measured by the SMILE-FFQ compared with repeat 24-hour recalls



(a) Total Sugars FFQ1 compared with 24HR; (b) Total Sugars FFQ2 compared with 24HR;
(c) Free Sugars FFQ1 compared with 24HR; (d) Free Sugars FFQ2 compared with 24HR.
FFQ 1 and 2 refer to the same tool (SMILE-FFQ) administered before (FFQ1) and after (FFQ2) the recalls.

Reproducibility of the SMILE-FFQ

Reproducibility was assessed by comparing total and free sugars values obtained by SMILE-FFQ1 and SMILE-FFQ2. Agreement at the individual level (Table 3.6) was either good (Chi-Square, Pearson) or acceptable (Weighted Kappa).
Cross-classifications demonstrated good agreement between the two methods in classifying participants into tertiles, with less than 10% of participants misclassified into an opposite tertile for both total and free sugars.

Table 3.6 Reproducibility of the SMILE-FFQ[a]

	Correlation	Cross-Classification			
		Chi-Square [c]			
	Pearson [b]	Similarly Classified (%)	Adjacently Classified (%)	Dissimilarly Classified (%)	κ_w [d]
Total Sugars	0.494 **	51.5	40.0	8.5	0.359
Free Sugars	0.693 **	59.0	34.8	6.3	0.464

[a] Reproducibility was assessed by comparing results from the SMILE-FFQ administered to the same cohort a minimum of six weeks apart.
[b] Outcome criteria correlation coefficient (Pearson): Good: ≥ 0.50; Acceptable: 0.20 – 0.49; Poor: < 0.20.
[c] Outcome criteria cross-classification (Chi Square): Good: ≥ 50% similarly classified and ≤ 10% dissimilarly classified; poor < 50% similarly classified and > 10% dissimilarly classified.
[d] Outcome criteria Weighted Kappa: good ≥ 0.61; acceptable 0.20 – 0.6; poor < 0.20.
** $p < 0.01$.

Comparison at the group level found no significant difference between the two FFQs for mean free sugars intakes, indicating good agreement; however, for total sugars, there was a significant difference, indicating poor agreement (Table 3.7).

The Bland Altman Index showed either 5.3% or 6.3% of participants falling outside of the limits of agreement, with total sugars close to the acceptable cut-off of 5%. The limits of agreement appear to be wide when compared to the mean, SD, and range of reported intakes (Table 3.3).

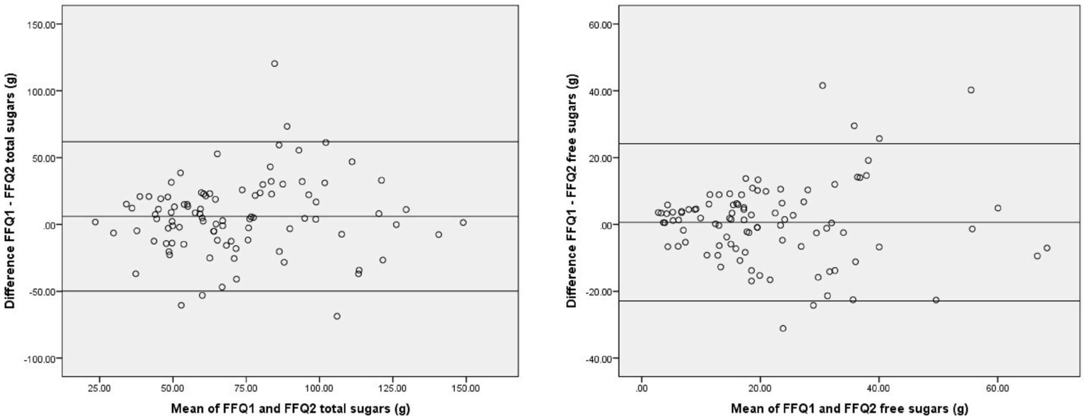
Table 3.7 Bland Altman statistics for repeat administrations of the SMILE-FFQ[a]

	Mean Difference ± SD (g)	Agreement *p* Value [b]	Limits of Agreement LOA (g)	Bland-Altman Index [c] (%)
Total Sugars	6.1 ± 28.5	0.027	−49.8, 61.9	5.3
Free Sugars	0.6 ± 12.0	0.583	−22.9, 24.2	6.3

[a] Reproducibility was assessed by comparing results from the SMILE-FFQ administered to the same cohort a minimum of six weeks apart.
[b] Outcome criteria nonparametric agreement (Wilcoxon): Good: $p > 0.05$; Poor: $p \leq 0.05$.
[c] Bland Altman index % of persons outside of LOA. Values ≤ 5% indicate good agreement.

Bland Altman plots demonstrated good agreement between repeat administrations of the SMILE-FFQ, as the data were scattered with no proportional bias (Figure 3.3). Linear regression also indicated that the slope of bias was not significantly different from zero for both measures ($p > 0.01$), suggesting there was no trend in differences in performance between the FFQs at varying levels of intake.

Figure 3.3 Bland Altman plots comparing total and free sugars measured by repeat administrations of the SMILE-FFQ



(a) (b)

(a) Total Sugars FFQ1 compared with FFQ2; (b) Free Sugars FFQ1 compared with FFQ2.

3.3.4 Discussion

Validity

Food Frequency Questionnaires aim to provide estimates of long-term dietary intake, and are generally considered unsuited to estimating absolute daily intakes of nutrients or capturing short-term dietary intakes (Thompson & Subar, 2013; Willett, 2013). The findings of this validation study reflect this, as the weakest agreement was observed in comparisons of absolute intake.

Combining the findings of the various tests, it is evident that individual level validity is more consistently rated as good than group level validity, and that the tool is most effective for ranking participants but not necessarily for determining absolute intakes of total and free sugars. The tendency of the tool to underestimate intakes in participants with lower 24HR values and overestimate intakes in those with higher values is consistent with other FFQs (Andersen et al., 2004; Huybrechts et al., 2009), and has a lesser impact on the accuracy of ranking than of absolute intakes. These results indicate that the SMILE-FFQ performs comparably to the 24HR as a measure of total and free sugars of individuals and to a lesser extent the group, and is therefore acceptable for use in observational studies of Australian toddlers if absolute sugars intakes is not an explanatory or outcome measure.

At present, the number of available tools which assess dietary intakes during early childhood is very small, and fewer still capture total sugars. To our knowledge, this is the first FFQ designed to measure free sugars in this age group (18–30 months), and the first Australian FFQ that has been validated for total or free sugars in any pre-school aged children (0–5 years). As such, comparison data in this age group are scarce. The National Infant Feeding Survey focuses on milk-feeding methods in the first two years of life rather than total diet (AIHW, 2011), and although the recent Australian Health Survey included participants as young as two, reporting of results for this age group is incomplete (ABS, 2014a).

Bell et al. (2014) recently developed a short food-group-based dietary risk assessment tool for use with Australian toddlers (aged 1–3 years). This 19-item screener generates a dietary risk score between 0 and 100, but is not designed to obtain nutrient values. Flood et al. (2013) developed a 17-item screener in FFQ style to rank Australian pre-school aged children (2–5 years) based on key dietary habits. Four questions pertained to major contributors of free sugars (biscuits, confectionery, soft-drink, fruit juice); however, two of these performed poorly against the reference method. Burrows et al. (2014) developed the 70-item Australian Recommended Food Score for Pre-schoolers (ARFS-P), but to date, this has only provided validation reporting against the FFQ from which it was developed, and scoring occurs at the food group rather than nutrient level, with a focus on core foods.

A FFQ has been developed for 12-month-olds in the United Kingdom (Marriott et al., 2009) and modified for use in New Zealand with toddlers aged 12–24 months (Mills et al., 2015b; Watson et al., 2015); however, it was not designed to capture free sugars, and the New Zealand validation studies do not report findings for total sugars. Nevertheless, it is rarely appropriate to use a tool designed for another population without adaptation and further validation, as food supply, composition, and terminology differ between countries. A notable example is the eight-item screener developed to assess the consumption of sugar snacks in Ugandan school-aged children (mean 12.4 years of age) (Kiwanuka et al., 2006). This tool lists tea and coffee as two of the eight food items included and as such is not transferable to Australian children. Although tea and coffee are significant contributors to sugar consumption of Ugandan children, the 2007 Australian National Children’s Nutrition and Physical Activity Survey reports a very low prevalence of consumption of tea and coffee in this age group, at 6.6% and 2.3%, respectively (CSIRO, 2008), and so the tool is not compatible with Australian research.

Challenges in dietary assessment of pre-school aged children

Dietary assessment in early childhood presents some unique challenges. Young children are unable to self-report, so proxy reporting must be used to collect the data from a surrogate (Livingstone et al., 2004; Magarey et al., 2011; Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013). Parents are not always aware of their child's complete dietary intake as feeding roles may be shared amongst other caregivers and child-care providers (Livingstone et al., 2004; Ortiz-Andrellucchi et al., 2010). In addition, toddlers tend to have higher amounts of plate waste than older children and adults, which makes estimating actual consumption more cognitively complex (Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013).

In addition, toddlers experience a unique food landscape. Portion sizes are small and highly variable, and the frequency of meals and snacks tends to be greater than for older children and adults. Young children also have strong appetite cues (Gahagan, 2012), and experience irregular patterns of rapid physical and cognitive growth. As a result, food intake and preferences have greater variability than that of adults in terms of both day-to-day intake and overall eating pattern, and change rapidly across the pre-school years (Livingstone et al., 2004; Ortiz-Andrellucchi et al., 2010; Thompson & Subar, 2013). An FFQ for this age needs to offer a wide range of lower-size portion options that include very small values. These small amounts seem negligible to overall nutritional intake; however, if lower end options are not provided, reporters may select the lowest available value, which may be several times larger than what was actually consumed. Also, due to the smaller energy and nutrient requirements of pre-school aged children, the small, frequent "tastes" of food may add up to a significant proportion of overall intake. The development of FFQs for this age bracket has often occurred by testing the validity of a tool originally designed for adults or older children, the portion sizes of which may be inappropriate and contribute to the common finding of overestimation (Andersen et al., 2004; Fumagalli et al., 2008; Huybrechts et al., 2009; Kobayashi et al., 2011).

These challenges limit the accuracy of most dietary assessment methods, including the SMILE-FFQ. The design of this FFQ attempts to minimise error from these challenges by targeting a narrow age range, providing portion size options specifically suited to toddlers and including only those foods of relevance to total and free sugars intakes rather than total diet. To reduce the difficulties arising from the high variability of the toddler diet, participants were asked to report "usual intake", rather than over a specified period of weeks. However, some participants may have found this more challenging as usual intake may be difficult to define.

The FFQ is well suited to comparing food group contribution to nutrient intake, as further interrogation of FFQ data can be conducted at the line item or block level. However, FFQs are unable to separate out individual sources at the single food level. For example, the SMILE-FFQ is able to identify major sources of sugar by food type (milk, yoghurt, biscuits, chocolate, breakfast cereal, table sugar, etc.), but is unable to describe precisely where, when, and in what combinations these foods are consumed.

Limitations of the study

Participation in the 24HR may have increased parent awareness of their child's food intake and influenced their responses to SMILE-FFQ2. This influence could partially explain the wide limits of agreement between repeat administrations of SMILE-FFQ, and why the total sugars results from SMILE-FFQ2 showed greater agreement with 24HR, a finding consistent with other studies of this type (Margetts & Nelson, 1997).

It is also likely that social desirability bias played a greater role in the 24HR, which were conducted by a dietitian via telephone interview, than the FFQs, which were self-administered online. This may explain some of the proportional bias; that participants who reported the highest sugars intakes via the online SMILE-FFQ provided more conservative estimates when reporting to the dietitian than those with lower SMILE-FFQ sugars intakes. Other studies support this theory, suggesting social desirability bias influences parents' reporting of their children's intakes, particularly in relation to their child's weight or higher levels of foods perceived as unhealthy (Börnhorst et al., 2012; Radnitz & Todd, 2016). The recent focus on reducing the intake of free sugars by the scientific community, coupled with current food fads in popular media that demonise sugar intake from any and all sources, may have exacerbated the rates of underreporting of foods high in sugars via telephone interviews. This does not, however, account for the underestimation at lower intakes.

There is some evidence to indicate that seasonal variation may affect dietary assessment responses; however, these effects are generally considered minor, with the greatest variation between different types of fruit and vegetables (Mohammadifard et al., 2011; Subar et al., 1994). This FFQ does not differentiate between types of fruit, but rather asks participants to estimate the overall frequency of consumption of any fruit. Additionally, the reference method (24HR) was administered in the middle of the data collection phase, which for most participants (90%), was completed within two months. This is likely to have ameliorated the effect of seasonal change on questionnaire responses.

A further limitation of this study design is the absence of a biomarker for validation. A urinary sugars biomarker based on a 24-h urine collection could be a suitable reference measure in future studies; however, research to date is limited by small sample sizes (Tasevska, 2015) and a 24-h urine collection in 18–30 month olds may be particularly challenging. In order to provide an estimate of usual intake, multiple collections would be required, resulting in a high cost and subject burden. In the absence of this, there is no reference instrument that can provide an accurate measure of a person's usual dietary intake. Repeat 24-h recalls are accepted as a suitable but imperfect reference instrument, considered to contain less systematic error than FFQs (NIH & NCI, 2018; Willett, 2013). The collection of intake data on three non-consecutive days in the 24HR may not have been sufficient to represent usual intake for some participants. Use of this imperfect reference instrument may have resulted in correlated errors between the two methods. Conversely, discrepancy between the SMILE-FFQ and 24HR may be the result of departure from true intake by either or both questionnaires.

Opportunities

As an online tool, the SMILE-FFQ is easily administered and shows potential for use in future Australian dental observational studies involving toddlers and pre-schoolers. If, however, the cohort is substantially different from the one described here, or the tool is modified in any way, an external or internal validation study is required to assess validity (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). Further information about the questionnaire is available from the researchers upon request. The SMILE-FFQ has recently been administered to a cohort of approximately 1600 families as part of the NHMRC-funded Study of Mothers' and Infants' Life Events affecting oral health (Do et al., 2014).

3.3.5 Conclusions

The SMILE-FFQ has been developed to capture total and free sugars intake within the unique food landscape of Australian toddlers by parent report. Investigations of relative validity and repeatability suggest that this tool performs similarly to repeat 24-hour recalls at ranking participants, with a tendency to underestimate intakes in participants with lower reported 24HR values and overestimate intakes in those with higher reported values. The findings of this study suggest that the SMILE-FFQ is suitable for use in observational studies of Australian toddlers wanting to use ranked total and free sugars intakes. As with all FFQs, it is recommended that future administrations of the tool are accompanied with internal or external calibration or further validity testing if administered to a dissimilar cohort.

Supplementary Materials: The following are available online at www.mdpi.com/, Supplementary Material: SMILE Food Frequency Questionnaire (Appendix D).

Acknowledgments: This research is part of the NHMRC funded Study of Mothers and Infants Life Events affecting oral health (SMILE) project (APP1046219).

Author Contributions: GD and JS conceived and designed the study; GD drafted the FFQ in consultation with JS, AB, and LD; GD and AM designed the Access database for pairing FFQ and nutrient data; GD, AM, and JS analysed the data; GD wrote the paper in consultation with all authors.

Conflicts of Interest: The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in collection, analysis or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

3.4 Additional Investigation: Fluoride Validity in the SMILE-FFQ

As a key confounding variable in early childhood caries investigations, fluoride sources were considered in the development of line items for the SMILE-FFQ, described in 3.3.2. Although we obtained a measure of fluoride from the SMILE-FFQ, it was not considered in the initial validity testing, as there was no comparable intake value produced by the reference instrument. AUSNUT2011–13 does not list fluoride for any of the 5740 foods in the database (FSANZ, 2014) and so an intake value could not be derived from the 24-hour recalls. The only alternative Australian database at the time was NUTTAB 2010, which lists fluoride for approximately 550 foods (FSANZ, 2011b). This was updated and renamed the Australian Food composition Database (Release 1) in 2019, but still only lists fluoride for 592 foods (FSANZ, 2019a).

We attempted to address this in 2017, via a student research project to develop a database of estimated fluoride values for use with AUSNUT2011–13. This project was undertaken by Jodie Roberts in the Curtin Masters of Dietetics program, supervised by the candidate (GD) who conceived the study, established the protocol for developing the database, provided initial training in the use of the protocol, and assisted with resolving uncertainties as they arose; with co-supervision by Professor Jane Scott. The database was used by the candidate to produce an estimated fluoride value from the 24-hour recalls, in order to conduct validity testing of the fluoride values produced by the SMILE-FFQ. The methods and results are presented here.

3.4.1 Methods

After the development of the fluoride database, validity testing of the SMILE-FFQ for fluoride followed the methods previously described for total and free sugars, in 3.3.2 Materials and Methods, using the same 24-hour recall data provided by the validation cohort (*n* = 95).

Development of an estimated fluoride database for AUSNUT2011–13

The estimated fluoride database was developed by assigning existing fluoride values to each food item in AUSNUT2011–13. The fluoride values came from four published databases, following a hierarchical protocol that prioritised data from Australia and New Zealand and national databases over smaller, analytical studies. The hierarchy is depicted in Table 3.8.

Table 3.8 Fluoride database development: hierarchical protocol for assigning fluoride values to AUSNUT2011–13 foods

Priority	Source database	Database type	AUSNUT2011–13 foods assigned (*n*)
#1	NUTTAB 2010 (FSANZ, 2011b)	National, Australia	2411
#2	Cressey et al. (2009)	Analytical, and pooled from Australian and New Zealand data	1861
#3	United States Department of Agriculture (2005)	National, United States of America	469
#4	Zohoori and Maguire (2015)	Analytical, United Kingdom	134
#5	Recipe approach, using sources #1–4		398
#6	*No value assigned*		*467*
Total AUSNUT2011–13 Foods			**5740**

All foods in NUTTAB2010 with a fluoride value were assigned to one or more corresponding foods in AUSNUT2011–13, accounting for 2411 out of the 5740 foods in the database. The remaining foods were assigned a value by checking the three remaining databases in order until a suitable value was obtained. The three databases in order of priority were 1) a New Zealand fluoride database that was established by pooling analytically derived data from other New Zealand studies (Cressey et al., 2009) which provided values for a further 1861 foods; 2) the United States Department of Agriculture National food composition database (United States Department of Agriculture, 2005) accounting for a further 469 foods; and 3) an analytically derived database established in the United Kingdom (Zohoori & Maguire, 2015) which provided 134 foods.

During this process, when no specific fluoride value was available, the broader food group classification level was used to assign a value if appropriate. For example, the food group *19101, Milk, cow, fluid, regular whole, full fat* contains nine food items, including regular, organic, A2, lactose free etc. As there was only a fluoride value for regular full cream milk available, this was applied to all foods within that category. If some items within the food group category had a specific fluoride value available, these values were retained, so the new value was only applied to those with missing fluoride information. Foods groups for which it was not appropriate to apply the value across the whole level included items with very different water contents, for example the food group *12401, Pasta and noodles, wheat based, other than instant noodles* includes both cooked and uncooked pasta.

Where there was no suitable value that could be applied to missing items across the whole food group, fluoride values for any foods within that group were averaged to fill the gaps. For example, the food group *15101, Fin fish, fresh, frozen* contains 123 foods, so average values for all steamed fish, all grilled fish and all raw fish were determined and applied to all foods using that cooking method within the group.

For mixed dishes that did not have an overall fluoride value, a recipe approach was used to assign a value, using the same hierarchy for selecting fluoride values for the component ingredients. This method contributed values to a further 398 foods.

Finally, there were 467 foods that had no comparable fluoride value. These included native Australian fruits, vegetables and meats, which to our knowledge have not been analysed for fluoride concentration in the published literature. Many other items represented African and Asian cuisines, such as sago, wonton, millet, tofu, wasabi, miso, taro, okra etc. Some items were dry mix powders such as custard powder and cake mix, while others were raw uncooked grains such as uncooked rice, and dry couscous. These items were left blank and therefore imputed as zero.

The resulting database provided an estimate of fluoride values, matched to AUSNUT2011–13.

Validation methods

Mean fluoride intake values for each participant were derived in the same way as free sugars values (see 3.3.2, Data collection). For the SMILE-FFQ, the scoring database included fluoride values for all line items, and was linked to participant responses in the same way as free sugars, using Microsoft Access version 15

(Microsoft Corporation, 2013, Washington, DC, USA). For the 24-hour recalls that had been entered into FoodWorks for sugars validity testing, the AUSNUT2011–13 food codes were used to link the new fluoride database to the existing food intake data via Microsoft Access.

Drinking water was not part of the probing protocol for the 24-hour recalls, so this was inconsistently reported by participants. If water was reported as a drink, it was recorded on the initial interview record, but not entered into FoodWorks. This is a point of difference from SMILE-FFQ, which includes a line item for tap water in the beverages section. To resolve this, fluoride values for the SMILE-FFQ were generated with and without the inclusion of tap water, and validity testing was conducted based on fluoride intakes from sources other than drinking water.

Data were analysed in SPSS version 25 (IBM SPSS Statistics for Windows, New York, USA), with log-transformed data for all but Bland Altman analyses, using the same methods, tests and outcome cut-offs as total and free sugars, described in 3.3.2.

3.4.2 Results

Approximately 3% of food items consumed in the 24-hour recalls for this cohort (n = 95) were not matched to a fluoride value, due to missing information in the fluoride database. These foods are thought to have contributed only minor fluoride amounts to the diet, as they included ingredients only consumed by 1 or 2 participants, or in small amounts. Commercial sushi and some homemade pasta dishes were notable exceptions, with missing fluoride values that may have contributed substantially to overall intake for those that consumed these items.

Fluoride intake from sources other than drinking water

Table 3.9 reports fluoride intake as measured by SMILE-FFQ at two time points and the repeat 24-hour recalls. Measures of normality before and after log transformation are also presented. Mean and median fluoride intakes from sources other than drinking water in the reference measure were more than double that of either FFQ.

Table 3.9 Fluoride intake as measured by the SMILE-FFQ, and repeat 24-hour recalls

	Mean ± SD	Median	Range	Percentile		Normality			
						Raw		Transformed [b]	
				25th	75th	Skew	K-S [c] p	Skew	K-S [c] p
Fluoride: All sources									
FFQ1 (μg)	719 ± 415	656	189–2307	418	933	1.46	0.003		
FFQ2 (μg)	694 ± 423	590	175–2204	419	805	1.68	0.000		
Fluoride: Sources other than drinking water									
FFQ1 (μg)	198 ± 142	164	34–983	116	224	2.81	0.000	0.21	0.082
FFQ2 (μg)	171 ± 113	143	40–841	99	211	2.74	0.001	0.17	0.200
24HR (μg)	404 ± 165	373	108–863	294	496	0.704	0.077	–0.56	0.051

FFQ: Food Frequency Questionnaire; 24HR: repeat 24-hour recalls.
[a] FFQ 1 and 2 refers to the same tool (SMILE-FFQ) administered before (FFQ1) and after (FFQ2) the recalls.
[b] Natural Log Transformation.
[c] Kolmogorov-Smirnov test for normality.

Relative validity and reproducibility of SMILE-FFQ for fluoride

Agreement between 24-HR and each administration of the SMILE-FFQ (Table 3.10) was poor for most tests, with the Pearson correlation the only result in the acceptable range. Reproducibility tests were better, with good agreement between repeat administrations of the FFQ for all except weighted Kappa, which was acceptable.

Table 3.10 Relative validity[a] and reproducibility[b] of the SMILE-FFQ for fluoride

	Correlation	Cross-Classification			
	Pearson[d]	Similarly Classified (%)	Adjacently Classified (%)	Dissimilarly Classified (%)	κw[f]
24HR v FFQ1[e]	0.373 **	34.7	50.5	14.7	0.098
24HR v FFQ2	0.308 **	43.1	43.1	13.7	0.208
FFQ1 v FFQ2	0.534 **	51.5	39.0	9.5	0.344

[a] Relative Validity was assessed by comparing results from the SMILE-FFQ to those of repeat 24-Hour recalls.
[b] Reproducibility was assessed by comparing results from the SMILE-FFQ administered to the same cohort a minimum of six weeks apart.
[c] FFQ 1 and 2 refer to the same tool (SMILE-FFQ) administered before (FFQ1) and after (FFQ2) the recalls.
[d] Outcome criteria correlation coefficient (Pearson): Good: ≥ 0.50; Acceptable: 0.20 – 0.49; Poor: < 0.20.
[e] Outcome criteria cross-classification (Chi Square): Good: ≥ 50% similarly classified and ≤ 10% dissimilarly classified; Poor: < 50% similarly classified and > 10% dissimilarly classified.
[f] Outcome criteria Weighted Kappa: Good: ≥ 0.61; Acceptable: 0.20 – 0.60; Poor: < 0.20.
** $p < 0.01$. FFQ: Food Frequency Questionnaire; 24HR: 24-hour recalls.

Nonparametric agreement at the group level was also poor, with a significant difference between the 24-hour recalls and each administration of the FFQ, and borderline significance ($p = 0.05$) for the repeat administrations (Table 3.11). Limits of agreement were considered wide when compared to mean intakes and the Australian nutrient reference value for fluoride for this age (NHMRC, 2017a).

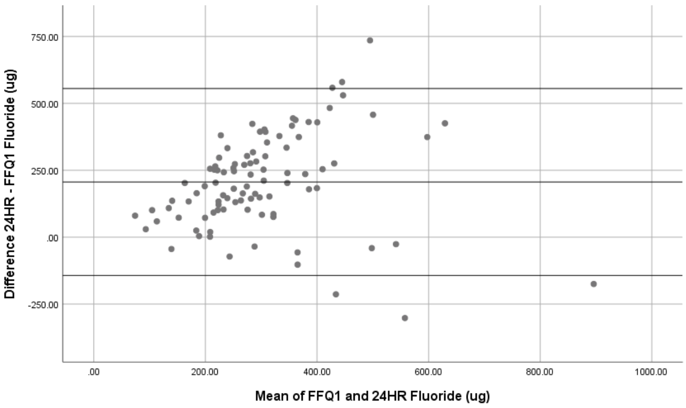
Table 3.11 Bland Altman statistics for the SMILE-FFQ for fluoride

	Mean Difference ±SD (µg)	Agreement *p* Value [b]	Limits of Agreement (µg)	Bland-Altman Index [c] (%)
24HR v FFQ1	206 ± 178	0.000	−143, 556	4.2
24HR v FFQ2	233 ± 178	0.000	−117, 583	6.3
FFQ1 v FFQ2	27 ± 124	0.050	−215, 269	6.3

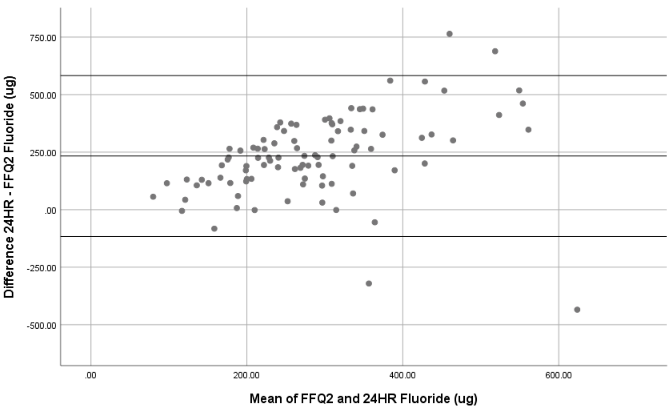
FFQ: Food Frequency Questionnaire; 24HR: 24-hour recalls.
[a] FFQ 1 and 2 refers to the same tool (SMILE-FFQ) administered before (FFQ1) and after (FFQ2) the recalls.
[b] Outcome criteria nonparametric agreement (Wilcoxon): Good: $p > 0.05$; Poor: $p \leq 0.05$.
[c] Bland Altman index % of persons outside of limits of agreement. Values ≤ 5% indicate good agreement.

Visual inspection of the Bland Altman plots (Figure 3.4) suggested a positive slope and increased variability as the magnitude of measure increased for all three measures. Linear regression indicated proportional bias was present between FFQ1 and FFQ2 ($p = 0.009$) and between the 24-hour recalls and FFQ2 ($p < 0.001$), but not present between the 24-hour recalls and FFQ1 ($p = 0.123$).

Figure 3.4 Bland Altman plots for fluoride

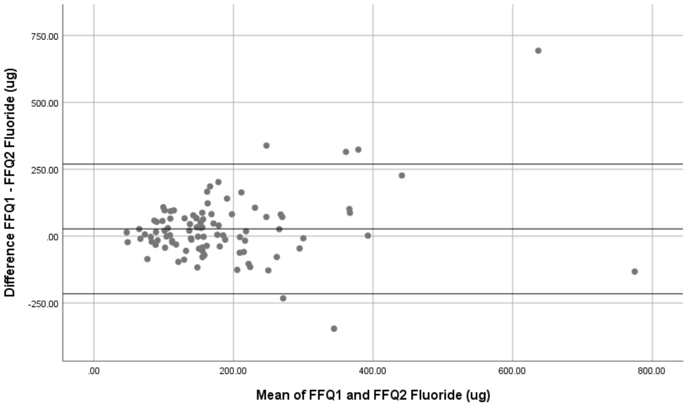


(a)



(b)

continued



(c)

SMILE-FFQ administered before (FFQ1) & after (FFQ2) repeat 24-hour recalls (24HR):
(a) FFQ1 compared with 24HR; (b) FFQ2 compared with 24HR; (c) FFQ1 compared with FFQ2

3.4.3 Discussion and Conclusions

The SMILE-FFQ does not appear to provide a valid measure of fluoride intakes, as evidenced by consistent findings of poor agreement across a range of statistical tests.

A key reason for this discrepancy is the absence of a question in the SMILE-FFQ about grains such as bread, rice, pasta, quinoa, millet etc. This was removed during questionnaire development, as it is not a key contributor to total or free sugars intakes, however several recent investigations have found it to be the highest solid food source of fluoride (FSANZ, 2011a; Rankin et al., 2012).

If grains had been included in the SMILE-FFQ this validity testing would still have been limited by a range of methodological compromises. In addition to those inherent in dietary assessment (discussed in 3.3.4), the absence of drinking water in the 24-hour recalls and the lack of national fluoride data limit the findings. The resulting fluoride values produced from the reference measure are less reliable than the other nutrient values produced with AUSNUT2011–13. This makes it difficult to assess whether discrepancies between the SMILE-FFQ and the 24-hour recalls are due to poor validity of the new tool, or inaccurate representation of 'true' intake in the reference measure. It is most likely a combination of both.

The absence of fluoride in national nutrient databases makes future work in this area challenging. The estimated database produced here was a useful starting point, however analytically derived fluoride values were highly variable for similar products across the four reference databases. The fluoride content of foods and beverages varies based on geographical location, local water fluoridation concentrations and farming practices such as fertilizer and pesticide uses (Cressey et al., 2009). The hierarchical protocol for assigning fluoride values to the database prioritised data from Australia and New Zealand, in order to best accommodate these geographical, water and farming variations. Approximately three quarters of foods in AUSNUT2011–13 were assigned a fluoride value from the Australian and New Zealand data sources. Future directions for dietary assessment of fluoride should involve sample analysis of the Australian food supply in order to obtain current and geographically representative values. In the absence of this, ongoing updates to this preliminary fluoride database, as more accurate and representative values emerge, will allow for continued refinement of this initial work.

Several of the limitations here result from methodological decisions that served the primary aim of the SMILE-FFQ, which was to capture total and free sugars. The SMILE-FFQ has met this primary aim, and is considered valid for these nutrients in this population. The removal of grains from the questionnaire is a regrettable oversight, and future uses of SMILE-FFQ could be improved by the addition of line items relating to grains, with follow up validity testing against a reference measure that includes estimations of drinking water, using the most reliable fluoride data that is available.

3.5 Administration of the SMILE-FFQ to the SMILE Cohort

For administration to the SMILE cohort, the SMILE-FFQ was added to the end of the 2-year dental questionnaire. This was sent to parents when their child reached 2 years of age, delivered in their preferred format, either online or paper-based. The SMILE research team in Adelaide co-ordinated participant reminders and follow-up, with the nutrition team in Perth addressing queries relating to SMILE-FFQ, and providing technical support for the online questionnaire.

SMILE-FFQ responses from the paper-based questionnaire were entered into Microsoft Excel Version 16 (Microsoft Corporation, 2016, Washington, DC, USA), using a protocol for handling invalid responses (Appendix G). It was not possible to submit invalid responses in the online questionnaire due to force response features, so this protocol was not applied to the online responses. The two response sets were then combined, and the data checked for duplicates and incomplete responses.

3.5.1 Incomplete SMILE-FFQ Response Data

Incomplete responses to the SMILE-FFQ were handled conservatively, with participants excluded if they left more than 5% of questions blank. Willett (2013) observes that preventing blank responses is the best strategy, but that it is not always possible to completely avoid this. In SMILE, blank questions were minimised by the use of a force response function in the online version, however some unfinished online questionnaires were processed by the research team in order to obtain the completed dental questions that preceded the blank SMILE-FFQ (n = 16). Responses could not be forced in the paper-based questionnaires, and the large sample size and postal administration did not allow for immediate checking and follow up. There were 108 questionnaires excluded that were between 5% and 99% incomplete.

Studies in adults suggest that often the reason for blank FFQ responses are that a food was not consumed, so imputing a zero value for questionnaires with a small number of blanks is appropriate (Willett, 2013). Missing responses of participants with less than or equal to 5% missing were treated as zero (did not consume).

3.5.2 SMILE-FFQ Scoring and Audit

Responses were imported to Microsoft Access version 15 (Microsoft Corporation, 2013, Washington, DC, USA) for matching with the scoring database, and usual intake of total sugars, free sugars and fluoride were generated for each participant. After the additional validity testing revealed that the fluoride data were not valid measures of actual intake, they were not used in any further analysis.

The data were cross-checked against raw response data of a random sub-sample at each stage of the data cleaning and matching process. In addition, total and free sugars intakes were manually calculated for six participants, by matching response data for each line item with the lookup tables in the scoring database, and then compared to the final Access output. These six participants were selected somewhat arbitrarily, with a focus on checking a variety of responses, particularly for the additional questions that split the coding algorithm. All six manual calculations produced the same total and free sugars values as their corresponding Access output, indicating that the scoring database was working as expected.

3.5.3 SMILE-FFQ Reporting of Free Sugars

The FFQ design and validity testing were complete and administration to cohort had commenced prior to the release of the WHO (2015) guideline for sugars intake, which presented a clear mandate for reporting free sugars as a percentage of energy. Despite the original validity testing being conducted with sugars intake in grams, the use of percentage of energy was still aligned to the aim, which was to assess intakes of total and free sugars (see 1.3, p.2). As a result, methods of investigating intake of free sugars at 2 years of age in both grams and compliance with the WHO (2015) guideline were explored.

With a specific sugars focus, the SMILE-FFQ was not designed to capture total diet or energy intake, so the contribution of free sugars to energy intake cannot be determined from SMILE-FFQ responses. In order to report compliance to the WHO (2015) guideline, an Estimated Energy Requirement (EER) was calculated for participants based on the child's weight measured at 2 years. The method for this age used in the Australian Nutrient Reference Values (NHMRC, 2006) was followed, which uses an equation for children aged between 13 and 35 months from the Food and Nutrition Board of the Institute of Medicine (2006). At this age, the equation does not incorporate a physical activity level, and returns an EER in kilocalories, which was then converted to kilojoules using the multiplication factor of 4.184 (FAO, 2003). The equation for calculating EER in kilojoules (*EER_kJ*) from the child's weight in kilograms (*weight_kg*) is as follows:

$$EER\_kJ = [(89 \times weight\_kg - 100) + 20] \times 4.184$$

The percentage of EER from free sugars *(%EERFreeSugars*) was then calculated for comparison with the WHO guideline, using the energy value for sugars of 16.7 kilojoules per gram (FAO, 2003). This equation uses usual free sugars intake in grams (*FreeSugars_g*) and *EER_kJ* as determined above, and is as follows:

$$\%EERFreeSugars = [(FreeSugars\_g \times 16.7) \div EER\_kJ] \times 100$$

Weight data was collected at the dental examination after the child's second birthday. Of those who completed the SMILE-FFQ, 125 participants had missing weight data. Either they did not attend a dental examination, or the child or parent did not agree to the child being weighed at the examination. In order to maximise the sample size, these participants were assigned a reference EER for their age and gender (NHMRC, 2006). Sensitivity analysis determined that the inclusion of these participants did not change the overall findings, and is reported in Chapter 4 (see 4.4.3, p. 152).

3.6 Summary

As identified in Chapter 2 (see 2.5.2.1, p. 63), ECC research to date has been limited by insufficient dietary assessment methods. The use of robust dietary assessment at 1 and 2 years of age is a strength of SMILE. At 1 year of age, a 24-hour recall and 2-day estimated food record was used, applying the Multiple Source Method to derive an estimate of usual intake for total sugars, free sugars and energy. From this, the percentage of energy from free sugars was calculated for each child, for comparison to the WHO (2015) guidelines. A food frequency questionnaire (SMILE-FFQ) was designed to estimate usual intake of total and free sugars, and validated for use with this cohort at 2 years of age. The estimated energy requirement was determined from weight data at 2 years, and free sugars as a percentage of EER was calculated for each child.

The development and validation of the SMILE-FFQ addresses a current research gap; with the construction of a dietary assessment tool that is targeted, age-appropriate, representative of the current Australian food supply and assessed for external validity in a comparable cohort. The tool is suitable for use in future observational studies among Australian toddlers. Since this work, the SMILE-FFQ has also been revised for use with 5-year-olds as part of SMILE–2, and incorporates questions about cereal grains in order to improve fluoride measures. This work is outside of the scope of this thesis.

The resulting free sugars intakes of the SMILE cohort at 1 and 2 years of age are reported in the next chapter (Chapter 4), along with compliance with the WHO guidelines for sugars intake. The chapter also reports the major food sources of free sugars at both time points, and explores determinants of being a high free sugars consumer at this age.

Free sugars intake at 1 and 2 years of age is then used in investigations of infant feeding practices and ECC, in order to address the overall thesis aim in Chapter 5.

Chapter 4 RESULTS: FREE SUGARS INTAKES AT 1 AND 2 YEARS OF AGE

4.1 Overview

This chapter reports intakes and food sources of free sugars among participants in the SMILE cohort at 1 and 2 years of age, and briefly explores determinants of high free sugars consumption and tracking of participant intakes across the two time points. Data collection methods were detailed in Chapter 3.

The chapter commences with a brief discussion of some initial data investigations that occurred to inform methodological decisions for managing outliers (4.2), and is then presented by two papers. The findings for free sugars at 1 year of age were published in *Maternal and Child Nutrition*, presented in 4.3:

> Devenish, G., Ytterstad, E., Begley, A., Do, L., & Scott, J. (2019b). Intake, sources, and determinants of free sugars intake in Australian children aged 12-14 months. *Maternal & Child Nutrition*, e12692. doi:10.1111/mcn.12692

The findings at 2 years were published in *Nutrients* (open access), for the special issue titled *Dietary Intake and Eating Behavior in Children*, presented in 4.4:

> Devenish, G.; Golley, R.; Mukhtar, A.; Begley, A.; Ha, D.; Do, L.; Scott, J. (2019a). Free sugars intake, sources and determinants of high consumption among Australian 2-year-olds in the SMILE cohort. *Nutrients*, 11(1), 161, doi:10.3390/nu11010161

These are followed by a chapter summary in 4.5.

This work fills a gap in dietary monitoring and surveillance, by reporting free sugars intakes in Australian children at 1 and 2 years of age. To date, national dietary surveys have only collected data on Australians from 2 years of age onwards, and the National Infant Feeding Survey (AIHW, 2011) focused on select indicators in the first year of life, exploring milk-feeding methods and age of introduction of solids, rather than assessing the foods introduced, or nutritional adequacy of total diet.

The free sugars data at 1 and 2 years of age reported here are later used as a covariate in the investigation of infant feeding practices and early childhood caries (Chapter 5).

These papers address the tertiary aim of this work via objective 4, which is to *investigate intakes and food sources of free sugars at 1 and 2 years of age; compare findings to WHO intake recommendations and national data; and explore socio-demographic determinants of high free sugars consumption,* and provide data to contribute to objective 5 within the primary aim of this research (Table 1.1, p. 3).

4.2 SMILE Dietary Data Methods

The primary objective of the dietary data collection for SMILE is to provide explanatory variables for the SMILE outcome analyses. In order to report free sugars intakes, we conducted some initial investigations to inform methodological decisions for identifying and managing extreme misreporters and late responders. These initial investigations were not reported in either publication and so are briefly described here. The resulting data methods are described in the two papers that follow.

4.2.1 Extreme Misreporters and Implausible Intakes

The papers presented in this chapter each use a different method to handle participants who report implausibly high intakes of free sugars. In the absence of external biomarkers, there is no established consensus on the best approach in nutrition research, and commonly used methods focus on energy intakes, rather than other nutrients (Thompson & Subar, 2013; Willett, 2013). Priorities in method selection may also differ depending on the study population and outcomes, for example maintaining as large a sample size as possible may result in more participants with erroneous data, while prioritising greater accuracy of data will reduce the sample size. In addition, misreporting appears to occur more frequently in population sub-groups, including parents of overweight children, and those concerned about their child's weight status (Börnhorst et al., 2012; Radnitz & Todd, 2016). It is also not possible to determine whether the participants who were identified as having implausible intakes are true misreporters, nor whether those that remained are accurate reporters (Thompson & Subar, 2013; Willett, 2013).

Two methods for identifying likely misreporters are used here. Firstly, at 1 year of age we assigned each child with a reference EER for their age and sex (NHMRC, 2006), and then investigated the ratio of reference EER to reported Energy Intake. If EI:EER was between 0.54 and 1.46, participants were considered to have reported a plausible EI (Conn et al., 2009). In the first paper, analysis included the full cohort, followed by sensitivity analysis with those outside this plausible intake range removed.

At 2 years of age, we were unable to use the EI:EER method, as the SMILE-FFQ does not provide a measure of energy intake. Instead, we identified extreme outliers, defined as those participants who reported free sugars intakes greater than 3 standard deviations from the population mean (Atkins et al., 2016). In order to compare the participants at 1 and 2 years of age, this method was also applied to the 1-year data for the second paper. This led to the removal of a total of 25 participants from the 1 year (*n* = 11), 2 year (*n* = 13) or both (*n* = 1) datasets, resulting in the sample size discrepancy in the 1 year data between the two publications (Table 4.1).

Table 4.1 Comparison of SMILE dietary data sample sizes 1 and 2 years, using two methods for identifying misreporters

Publication	Method for identifying misreporters	Sample *n*	
		1 year (*n* = 828)	2 year (*n* = 1057)
Free Sugars at 12-14 months (Devenish et al., 2019b) Supplementary tables	EI : EER	699	n/a
Free Sugars at 2 years (Devenish et al., 2019a)	Free sugars Mean ± 3 SD	816	1043

EI: Energy Intake, EER: Estimated Energy Requirement, SD: Standard Deviation SMILE: Study of Mothers' and Infants Life Events affecting oral health

The most appropriate method to identify participants with implausible intakes when sugars is the outcome of interest is not known, however the selected methods have been employed in recent, Australian studies that have explored other nutrients of interest in similar cohorts (Atkins et al., 2016; Conn et al., 2009; Lioret et al., 2013). We have applied these methods cautiously, with the more exclusionary approach used in sensitivity analysis as a supplement to the analysis of the total sample.

4.2.2 Late Responses

Unsurprisingly, participants did not always return the dietary data in a timely manner. All parents were sent the questionnaires on or soon after their child's birthday, but responses were received as much as 1 year later (Table 4.2). A consistent methodological approach to late responses has not been established, with recent Australian studies in similar cohorts excluding those outside of a specified response window (Amezdroz et al., 2015; Lioret et al., 2013; Spence et al., 2018), adjusting for participant age (Bell et al., 2016b), or not reporting taking any action (Atkins et al., 2016; Bell et al., 2013; Conn et al., 2009; Webb et al., 2008),

A further complication is that the age values used in SMILE are imperfect measures. At 1 year, age was calculated from date of birth, based on the date of the 24-hour recall (i.e., intake day 1). Although participants were then allocated two dates in the following ten days to complete the diary, some may not have filled it in on these days, and may have taken weeks to complete and return it. When a response was returned late, there was no way to establish whether the participants had completed the food record within the timeframe but returned it late, or whether they had also completed the record late.

At 2 years, the SMILE-FFQ was completed via the participants' choice of online or paper-based questionnaire, and the recorded date of completion varied between these methods. For online responses, age was calculated from date of birth based on the date of online submission, whereas for paper-based responses age was calculated from date of birth based on the date the SMILE team received the questionnaire by mail. As a result, the mean age of completion of the paper-based responses was slightly older, which would reflect the delay between questionnaire submission via post, and receipt by the SMILE team.

Table 4.2 reports the percentage of participants who provided complete dietary data in 1-month increments from their birthday. For the 1-year data collection, most participants (97%) completed the dietary assessment within 3 months of their first birthday. At 2 years of age, the range was wider, with 89% completing the dietary assessment within 3 months of their second birthday, and 98% doing so within 6 months.

Table 4.2 Age at time of dietary assessment, SMILE participants at 1 and 2 years

1 Year (*n* = 828)			2 Years (*n* = 1043)		
Age (months)	***n* (%) of responders**	**Cumulative percent**	**Age (months)**	***n* (%) of responders**	**Cumulative percent (valid)**
<13	507 (61.2)	61.2	<25	490 (47.0)	48.3
13 – <14	251 (30.3)	91.5	25 – <26	295 (28.3)	77.3
14 – <15	44 (5.3)	96.9	26 – <27	114 (10.9)	88.6
15 – <16	13 (1.6)	98.4	27 – <28	44 (4.2)	92.9
16 – <17	10 (1.2)	99.6	28 – <29	36 (3.5)	96.5
17 – <18	2 (0.2)	99.9	29 – <30	13 (1.2)	97.7
18 – <19	1 (0.1)	100.0	30 – <31	6 (0.6)	98.3
≥19	0		31 – <32	10 (1.0)	99.3
			32 – <33	2 (0.2)	99.5
			33 – <34	2 (0.2)	99.7
			34 – <35	1 (0.1)	99.8
			≥35	2 (0.2)	100.0
missing	*0*		*missing*	*28 (2.7)*	

Sensitivity analysis was performed on the 2-year data to investigate whether there was a difference in reported free sugars intakes between those with timely responses and those who responded later (Table 4.3). ‘Timely’ was defined as a response that was received within 3 months of the child’s second birthday. There was no significant difference between reported mean free sugars intakes of participants providing timely responses and those responding later.

Table 4.3 Sensitivity analysis timely vs later responders at 2 years SMILE-FFQ

		Free Sugars (g)		
Age (months)	***n* (%) of responders**	**Mean ± SD**	**Percentile 25^{th}, 75^{th}**	**p^a**
< 27	899 (88.6)	28.8 ± 23.3	12.4, 37.2	0.324
≥ 27	116 (11.4)	31.1 ± 26.0	14.5, 42.0	

[a] t-test

In summary, at 1 year of age, most participants responded within an acceptable timeframe. At 2 years of age, the range of response times was wider, however the methods of measuring age were more likely to overestimate age at time of recording, especially for the paper-based responses. In addition, the mean reported free sugars intake was not significantly different between timely vs late responders. As a result, we decided not to perform any age adjustments or apply age-based exclusion criteria.

4.3 Original Research: Intake, Sources and Determinants of Free Sugars Intake in Australian Children Aged 12-14 Months

Abstract: The consumption of free sugars is directly associated with adiposity and dental caries in early childhood; however, intake data in the first 2 years of life are limited. This cross-sectional analysis aims to identify major food sources of free sugars for Australian children aged 12–14 months and investigate factors associated with meeting the World Health Organization (WHO) Guideline for sugars intake. Three days of non-consecutive dietary data were collected via a 24-hr recall and 2-day food record for 828 participants. Usual intake of energy, total sugars, and free sugars were estimated, along with food group contributions to free sugars. Multiple logistic regression analysis was used to investigate factors associated with exceeding the WHO conservative recommendation that less than 5% of energy should come from free sugars. Mean free sugars intake was 8.8 (SD 7.7, IQR 3.7 – 11.6) g/day, contributing 3.6% (SD 2.8, IQR 1.6 – 4.8) of energy. Only 2.4% of participants exceeded the WHO recommendation that less than 10% of energy should come from free sugars, with 22.8% of participants exceeding the < 5% recommendation. Children from households with greater socio-economic disadvantage (IRSAD < 5, OR = 1.94) and in the lowest income bracket (OR = 2.10) were more likely to have intakes greater than or equal to 5% of energy. Major food sources of free sugars were commercial infant foods (26.6%), cereal-based products (19.7%), namely, sweet biscuits (8.3%) and cakes (7.6%), followed by yoghurt (9.6%), and fruit and vegetable beverages (7.4%). These findings highlight the substantial contribution of infant foods to free sugars intakes and provide further evidence that dietary intakes are influenced by social determinants.

Keywords: 24-hour recall, 2-day food record, food sources, dietary intakes, early childhood, free sugars, infant feeding.

4.3.1 Introduction

Food intakes in the first 2 years of life shape taste preferences and healthy eating habits, which can have lasting health implications throughout life (Birch & Doub, 2014; Lillycrop & Burdge, 2011). In particular, intake of foods high in free sugars is associated with increased body weight and dental caries in early childhood (WHO, 2015). Dental decay is the leading cause of preventable hospitalisations among Australian children, and prevalence is increasing (AIHW, 2012; ARCPOH, 2011). This disease burden is consistently higher among those with lower socio-economic status, and income-related inequality in caries experience of Australian children appears to be widening (Armfield & Spencer, 2008; Do et al., 2010).

Diet quality also follows a social gradient (Darmon & Drewnowski, 2008). Socio-economic disparity has been observed in Australian children's consumption of energy-dense, nutrient-poor foods and beverages (ABS, 2015; Bell et al., 2016a; Cameron et al., 2012), many of which are high in added or free sugars. The World Health Organization (WHO) recommends reducing intakes of free sugars in adults and children to less than 10% of total energy intake and conditionally recommends a further reduction to less than 5% of energy (WHO, 2015). The WHO definition of free sugars includes “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” (2015, p. 4).

An analysis of the National Nutrition and Physical Activity Survey revealed that just over 50% of children aged 2–3 years exceeded the WHO recommendation that less than 10% of total energy should come from free sugars, and 93% exceeded the less than 5% recommendation (ABS, 2016b). Secondary analysis of the Australian National Children's Nutrition and Physical Activity Survey found even higher rates, with 69% of 2 to 3 year-olds exceeding the 10% recommendation and 98% exceeding the 5% recommendation (Louie et al., 2016). Both studies reported increasing intakes of free sugars with age through childhood and adolescence, along with greater percentage of dietary energy from free sugars, and an increasing number of children and adolescents exceeding the WHO recommendations (ABS, 2016b; Louie et al., 2016).

Most children commence life on a diet devoid of free sugars, as breast milk and the majority of infant formula contain no added or free sugars. However, in the absence of national nutrition monitoring in the first 2 years of life in Australia, little is known of the contribution of free sugars to the diets of young children as they transition from a milk-based diet to one that reflects family intakes, and at what point free sugars enter the diet. The aims of this study are to investigate major food sources of free sugars for Australian children aged 12–14 months; to compare the percentage of energy from free sugars to the WHO guidelines; and explore socio-demographic factors associated with exceeding the WHO guidelines in this population

Key Messages

- Only 2.4% of 12–14 month olds consumed ≥ 10% of energy from free sugars, although 22.8% consumed ≥ 5% energy from free sugars
- Children from households with greater socio-economic disadvantage and in the lowest income bracket were more likely to exceed the WHO < 5% recommendation
- With the exception of commercial infant foods, the major food sources of free sugars as children transitioned to the family diet were comparable with those seen later in life.
- These findings highlight the substantial contribution to free sugars made by infant and toddler foods, along with the early emergency of dietary behaviours and influences of social determinants.

4.3.2 Methods

This study is a cross-sectional analysis of dietary data collected by the Study of Mothers' and Infants' Life Events affecting oral health (SMILE), a longitudinal birth cohort study based in Adelaide, Australia. Details of the SMILE protocol are reported elsewhere (Do et al., 2014). Briefly, 2,147 mothers and 2,181 newborns, including 34 pairs of twins, were recruited from the three major maternity hospitals in Adelaide from July 2013 until August 2014. All new mothers with sufficient English competency and not intending to move out of the greater Adelaide area within a year were invited to participate. Mothers in hospitals that service lower socio-economic areas were oversampled to compensate for anticipated higher attrition rates (Do et al., 2014).

Participants were invited to complete questionnaires at recruitment, and when their child reached 3, 6, 12, and 24 months of age. These questionnaires collected information on dental and dietary behaviours and were available in paper, online, and telephone interview forms.

The Southern Adelaide Clinical Human Research Ethics Committee approved the study (HREC/50.13, approval date: 28 Feb 2013) as did the South Australian Women and Children Health Network (HREC/13/WCHN/69, approval date: 7 Aug 2013).

Dietary data collection at 12 months of age

When the child reached 12 months of age, mothers were invited to complete a 24-hour recall via telephone interview and 2-day food record, giving a total of two weekdays and one weekend day of dietary data.

A range of strategies were employed to maximise response rate and quality of dietary data. Participants were posted a food record booklet containing detailed instructions, a 1-day example food record, and images of food portion sizes and household measures. Approximately 1 week after the materials were sent, one of two research dietitians contacted participants via telephone to conduct the 24-hour recall. The five-step multipass method (ABS, 2014b) was used, with a modified forgotten foods list that replaced the question about alcohol with “any rusks or teething foods?”, and a uniquely designed probing protocol with specific questions for toddler foods in the detail cycle phase. During the recall, images in the food record booklet were used as a reference for obtaining quantity information over the phone.

At the end of the interview, mothers were allocated two non-consecutive days over the next 10-day period, on which to record their child's dietary intake using the food record booklet. Participants who completed the 24-hour recall received SMS and email reminders to return their food record.

The resulting 3 days of dietary data were entered into FoodWorks version 8 (Xyris Software, 2012–2017, Brisbane, Australia) using the current Australian food composition database, AUSNUT2011–13 (FSANZ, 2014). The data were double-entered by trained nutritionists/dietitians, using data entry protocols and calibration procedures for standardisation. When detail was lacking in the food record, the 24-hour recall was used for clarification purposes. For example, where a participant wrote only “milk” in the food record, the type (full-cream, skim, etc.) specified in the 24-hour recall was selected.

Due to the limited number of infant foods in the AUSNUT2011–13 database and the rapidly changing infant and toddler food market, 187 new foods were added to the database using information from product nutrition panels and manufacturer websites, mapped to a similar product in AUSNUT2011–13 for missing micronutrient values. These foods included fruit and vegetable pouches, ready to eat meal pouches and jars, dried and ready to eat flavoured infant cereals, infant and toddler yoghurts, snack bars, and other infant and toddler snack foods. Free sugars values for these products were determined by adapting the methodology of Louie et al. (2015) using the WHO (2015) definition of free sugars. This is the same method that was used to obtain free sugars values for the AUSNUT2011–13 database (FSANZ, 2016). Each new food was assigned an 8-digit food code, following the AUSNUT naming conventions. This resulted in the generation of two new 5-digit food subgroups that were not present in the current database: infant vegetable foods and infant snack foods.

After initial entry, descriptive statistics were used to identify outliers for the weight of food and energy consumed. The dietary data of these participants were rechecked for entry errors in FoodWorks and resolved as appropriate.

To determine food group contribution to nutrient intake, the AUSNUT2011–13 food group codes were used to group free sugars intakes by major and sub-major food groups. The infant foods sub-major group was further broken down into minor food groups, to accommodate the relative crudeness of the infant and toddler food group codes. Mean free sugars (g) were calculated for each food group among all participants and consumers only. For the consumer only analysis, consumers were defined as any participant who reported any food item from within the group, regardless of whether it contributed to free sugars.

Explanatory variables

A range of socio-demographic data were collected at recruitment, from which the following explanatory variables were generated for this analysis: mother's country of birth (“Australia and New Zealand”, “India”, “China”, “Asia–Other”, “UK”, and “Other”); mother's age at baseline; mother's education (“high school/vocational” and “some university and above”); mother's pre-pregnancy body mass index (“<18.49 kg/m^2”, “18.5–24.99 kg/m^2”, “25–29.99 kg/m^2”, and “≥30 kg/m^2”); total household income (“≤$40,000”, “$40,001–80,000”, and “≥$80,001”); parity (“1”, “2”, and “≥3”); and infant sex (“male” and “female”). Postcode was used to derive a measure of socio-economic status using the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD; ABS, 2013). Maternal smoking status at 12 months of age (“yes” or “no”) was obtained in the 12-month data collection phase. Milk-feeding method at 12 months of age (“Any breastfeeding”, “formula only”, and “neither”) was derived from the 12-month dietary data and is reported in detail elsewhere (Scott et al., 2016).

Outcome variable

The Multiple Source Method (Harttig et al., 2011) was applied to the 3 days of dietary data to estimate usual daily intake of total sugars, free sugars, and energy for each participant. The nutrient values were then used to calculate percentage of energy from free sugars, and determine the number of children meeting the WHO (2015) guideline. As very few children failed to meet the guideline of less than 10% energy from free sugars, failing to meet the more conservative guideline of less than 5% energy from free sugars was chosen as the outcome variable.

Sensitivity analysis

Sensitivity analysis was undertaken to account for extreme over and under reporting (Magarey et al., 2011). Estimated energy requirement (EER) was determined using a reference value (NHMRC, 2006), based on participant sex and age at 24-hour recall, as participant weight was unknown. This was used to determine the ratio of reported energy intake (EI) to EER for each child. Children with EI:EER below 0.54 or above 1.46 were deemed to have implausible EIs (Conn et al., 2009). Primary analyses were performed on the whole cohort and then repeated on those with plausible EIs after reapplying the Multiple Source Method (supplementary Table 4.9 and Table 4.10).

Statistical methods

Descriptive statistics, including means, standard deviations (SD), and interquartile ranges (IQR) were performed on the usual intake data. The percentage of children with free sugars intakes ≥ 5% and ≥ 10% of energy were also determined. For the food group contributions, the mean grams of free sugars were calculated for each food group among all participants and consumers only, and percentage contributions determined among all participants. Descriptive analysis was performed using SPSS version 24 (IBM SPSS Statistics for Windows, New York, NY, USA).

Multiple logistic regression was applied on the explanatory variables, for the dichotomous outcome < 5% or ≥ 5% of energy from free sugars. In the course of building a best model, the first analyses were performed within strata of the sample. Categorisations of continuous and categorical variables, as well as the interaction terms in the final model, are a result of these preliminary analyses. Model selection was also based on the Akaike information criterion (Akaike, 1974). The final model contains interaction between the child's sex and mother's country of birth (MCOB). The interaction coefficient is presented in combination with the sex and MCOB coefficients, as stratified by MCOB and stratified by child's sex. Multiple logistic regression was also used to compare the participant characteristics of responders to the non-responders. Due to multiple significance tests, a p-value below 0.01 was considered significant. Logistic regression analysis was performed using the statistical computing language R, version 3.4.2 (R Core Team, 2017).

4.3.3 Results

Participants

At least 1 day of dietary data was received for 1,175 participants; however, only 828 of these provided 3 days of usable dietary data and were included for analysis. Figure 4.1 depicts participant flow.

Figure 4.1 Participant flow

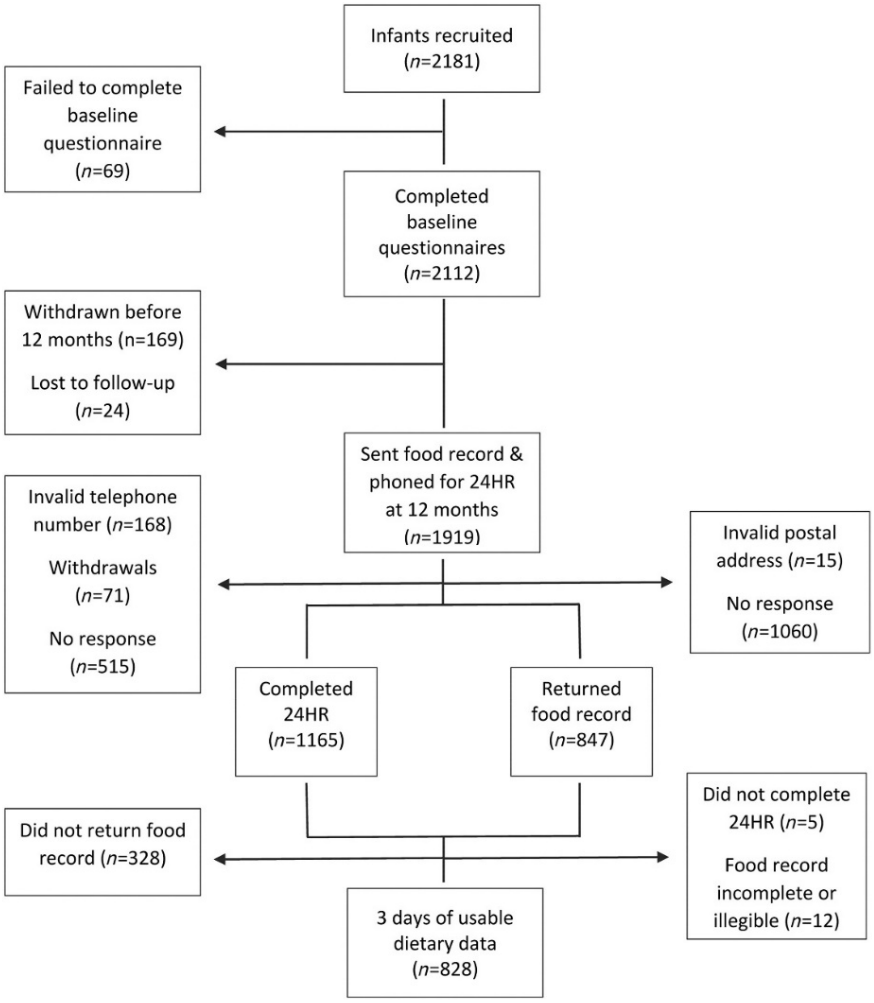


Table 4.4 describes participant characteristics for the 828 respondents, and those with ≥5% of energy from free sugars. Mean age of the children at time of the 24-hr recall was 13.1 (±0.8) months with most children (92%) aged between 12 and 14 months. The majority of mothers (74.1%) were born in Australia or New Zealand.

Response rates did not differ by pre-pregnancy body mass index category, education level, IRSAD score, smoking status, parity, household income group, infant's sex, or birthweight. Mothers that were 25–35 and those over 35 years of age were more likely to respond than those under 25 (odds ratio [OR] = 2.24, $p < 0.001$ and 2.37, $p < 0.01$, respectively). Mothers who were born in the United Kingdom or China were equally likely to respond as those born in Australia and New Zealand, whereas those from India (OR = 0.35, $p < 0.001$), other parts of Asia (OR = 0.37, $p < 0.001$), and other countries combined (OR = 0.43, $p < 0.01$) were less likely to respond compared to Australia and New Zealand born mothers. Women who provided complete dietary data at 12 months were generally representative of the socio-economic profile reported by the Pregnancy Outcome unit for South Australian births in 2013 (Scheil et al., 2015). Characteristics of study non-responders (n = 1353), and those above and below the WHO recommendations for free sugars intakes are provided in supplementary Table 4.8.

Table 4.4 Participant characteristics

	All Respondents		Respondents with Free Sugars ≥5% of Energy	
	n	**mean ± SD**	**n**	**mean ± SD**
Mother's age at birth (years)	826	30.8 ± 4.9	189	30 ± 5.3
Child's birthweight (g)	818	3397.9 ± 558.1	186	3402.6 ± 513.0
Child's age at 24HR (months)	807	13.1 ± 0.8	182	13.2 ± 0.9
	n	**%**	**n**	**% (row%)**
Child's sex				
Male	452	54.6	117	61.9 (25.9)
Female	376	45.4	72	38.1 (19.1)
Milk Feeding method				
Any Breastfeeding	288	34.8	50	26.5 (17.4)
Formula only	310	37.4	75	39.7 (24.2)
Neither	230	27.8	64	33.9 (27.8)
Mother's pre-pregnancy BMI[a] (kg/m^2)				
<18.5	41	5.2	5	2.9 (12.2)
18.5-24.99	436	55.6	93	54.1 (21.3)
25-29.99	167	21.3	41	23.8 (24.6)
≥30	140	17.9	33	19.2 (23.6)
Mother's smoking status at 12months				
no	746	92.0	170	91.4 (22.8)
yes	65	8.0	16	8.6 (24.6)
Total number of children				
1	389	48.6	90	48.4 (23.1)
2	291	36.3	62	33.3 (21.3)
≥3	121	15.1	34	18.3 (28.1)
Mother's Education				
High school / Vocational	356	43.2	102	54.5 (28.7)
Some University and above	468	56.8	85	45.5 (18.2)
Household Income ($)				
≤40,000	92	11.5	35	19.0 (38.0)
40,001-80,000	254	31.8	62	33.7 (24.4)
≥80,001	452	56.6	87	47.3 (19.2)
IRSAD[b]				
Deciles 1-4	293	35.6	92	48.7 (31.4)
Deciles 5-10	529	64.4	97	51.3 (18.3)
Mother's Country of Birth				
Australia or New Zealand	610	74.1	151	79.9 (24.8)
Other	213	25.9	38	20.1 (17.8)

[a] Body Mass Index (kg/m^2, where <18.5 = underweight; 18.5-24.99 = healthy weight range; 25-29.99 = overweight; ≥30 = obese)

[b] Index of Relative Socio-economic Advantage and Disadvantage (where 1 = most disadvantaged and 10 = least disadvantaged)

Free sugars intakes at 12 months of age

Mean usual intake of free sugars was 8.8 (SD 7.7, IQR 3.7 – 11.6) grams per day, contributing an average of 3.6 (SD 2.8, IQR 1.6 – 4.8) percent of daily energy (Table 4.5). In comparison with the WHO guidelines, 22.8% of participants consumed ≥ 5% of energy from free sugars, and only 2.4% of these consumed ≥ 10%.

Table 4.5 Free sugars intakes at 12 months

	Mean ± SD	Range	Percentile 25th, 75th
Free Sugars (g/day)	8.8 ± 7.7	0.22 – 115.3	3.7, 11.6
Total Sugars (g/day)	65.3 ± 17.4	18.4 – 181.05	53.1, 75.1
Energy (kJ/day)	4040 ± 836	1870 – 7948	3446, 4574
%Energy from Free Sugars	3.6 ± 2.8	0.12 – 34.3	1.6, 4.8
	n	**%**	
<5%Energy from Free Sugars	639	77.2	
≥5%Energy from Free Sugars	189	22.8	
≥10%Energy from Free Sugars	20	2.4	

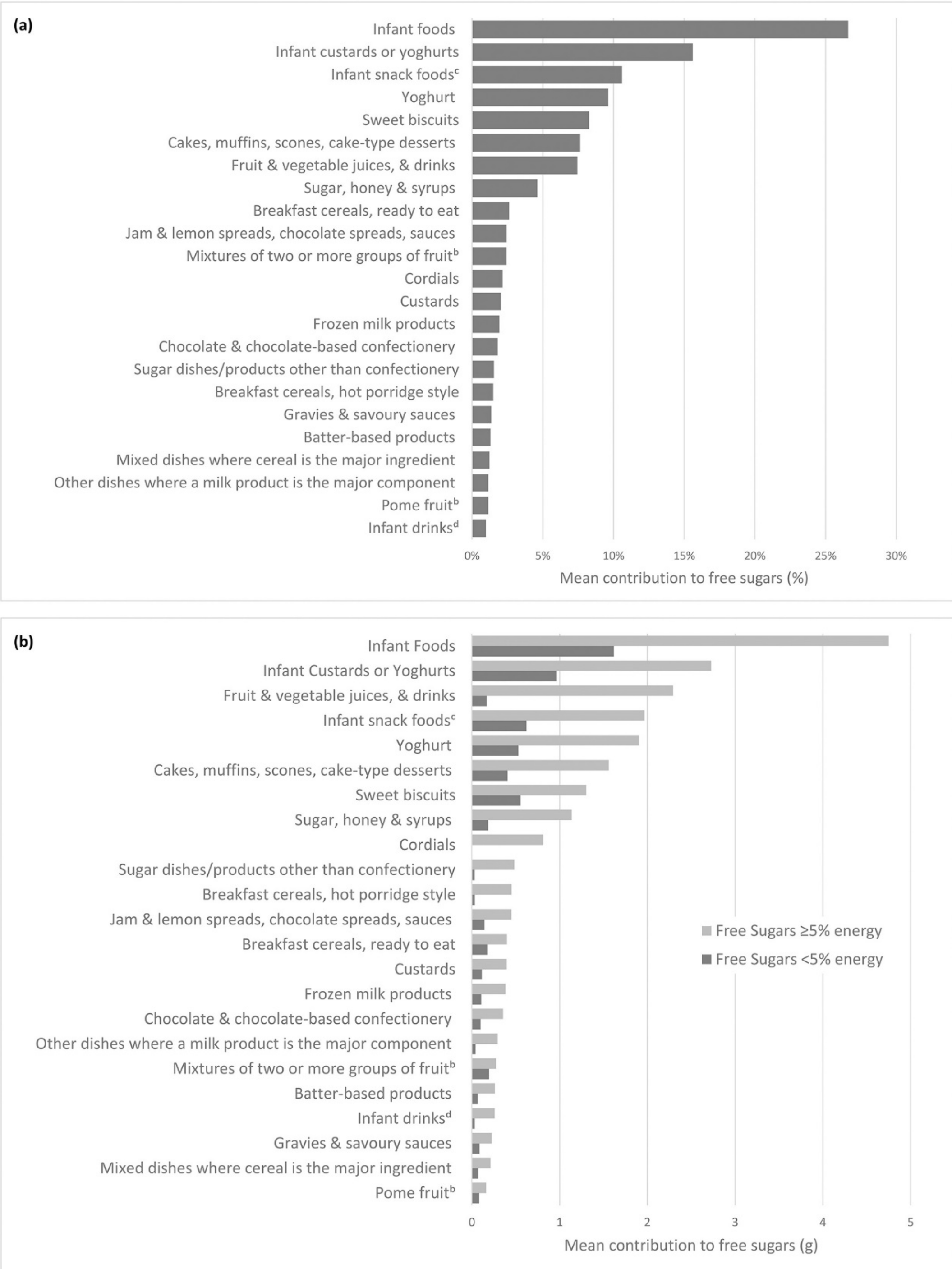
Food group contribution to free sugars

The most common sources of free sugars were commercial infant foods (27%), specifically infant custards and yoghurts (16%) and infant snacks [11%; Table 4.6, Figure 4.2 (a)]. This was followed by cereal based products and dishes (20%), namely, sweet biscuits (8%) and cakes, muffins, scones, and cake-type desserts (8%). Other substantial contributions came from yoghurt (10%) that was not specifically identified as infant yoghurt, and fruit and vegetable juices and drinks (7%).

Figure 4.2 (b) shows food group contribution to free sugars by participant adherence to the WHO < 5% recommendation. The most common sources of free sugars for participants below 5% were similar to those of the whole group. A notable exception was sugar-sweetened beverages. Both cordials and fruit and vegetable juices and drinks contributed a much lower proportion of free sugars to those with intakes below 5% of energy than to those above.

Among consumers only, food groups that supplied the greatest mean intakes of free sugars were cordials (46.6 g per consumer, *n* = 10) and fruit and vegetable juices and drinks (16.0 g, *n* = 101). These were followed by products other than confectionery where sugar is the major component (13.9 g, *n* = 24), which includes sugar-based desserts, water ice confection, gelato, and sorbet; then by cakes, muffins, scones and cake-type desserts (12.6 g, *n* = 132), and other dishes where milk or a milk product is the major component (11.8 g, *n* = 21), which includes dairy desserts (Table 4.6).

Figure 4.2 Contribution to free sugars by food group



(a) All participants. (b) By participant free sugars intake.
[a] Food groups providing < 1% contribution to free sugars not listed.
[b] Free sugars in fruit products and dishes come only from canned fruit and stewed fruit with added sugar.
[c] New category code created for infant- and toddler-specific snack foods not part of AUSNUT2011-13.
[d] Infant drinks category includes infant fruit juices but does not include infant formula or human breast milk

Table 4.6 Food group contributions to free sugars intakes

	All participants (n=828)		**Consumers**	
Food group[a]	**mean ± SD free sugars (g)**	**%contribution to free sugars**	**n (%)**	**mean ± SD free sugars (g)**
Non-alcoholic beverages	2.7 ± 14.9	10.3%	818 (98.8)	2.7 ± 15.0
Fruit & vegetable juices, and drinks	2.0 ± 9.5	7.4%	101 (12.1)	16.0 ± 22.7
Cordials	0.6 ± 10.8	2.1%	10 (1.2)	46.6 ± 91.8
Cereals & cereal products	1.3 ± 3.7	4.8%	810 (97.8)	1.3 ± 3.7
Breakfast cereals, ready to eat	0.7 ± 2.1	2.6%	495 (59.8)	1.1 ± 2.7
Breakfast cereals, hot porridge style	0.4 ± 3.0	1.5%	130 (15.7)	2.5 ± 7.2
Cereal based products & dishes	5.2 ± 9.0	19.7%	674 (81.4)	6.4 ± 9.6
Sweet biscuits	2.2 ± 4.4	8.3%	303 (36.6)	5.9 ± 5.6
Cakes, muffins, scones, cake-type desserts	2.0 ± 7.0	7.6%	132 (15.9)	12.6 ± 13.3
Mixed dishes where cereal is the major ingredient	0.3 ± 1.2	1.2%	251 (30.3)	1.0 ± 2.0
Batter-based products	0.3 ± 1.8	1.3%	107 (12.9)	2.6 ± 4.4
Fruit products & dishes[b]	1.2 ± 4.1	4.7%	788 (95.2)	1.3 ± 4.2
Pome fruit	0.3 ± 1.7	1.1%	398 (48.0)	0.6 ± 2.5
Mixtures of two or more groups of fruit	0.6 ± 3.5	2.4%	69 (8.3)	7.6 ± 9.6
Milk products & dishes	4.0 ± 8.1	15.1%	760 (91.8)	4.3 ± 8.4
Yoghurt	2.5 ± 6.3	9.6%	373 (45.0)	5.6 ± 8.4
Frozen milk products	0.5 ± 2.4	1.9%	70 (8.5)	6.0 ± 5.9
Custards	0.5 ± 3.0	2.0%	61 (7.4)	7.2 ± 8.4
Other dishes where milk or a milk product is the major component	0.3 ± 2.3	1.1%	21 (2.5)	11.8 ± 8.8
Savoury sauces & condiments	0.4 ± 1.2	1.5%	297 (35.9)	1.1 ± 1.9
Gravies & savoury sauces	0.4 ± 1.2	1.3%	255 (30.8)	1.1 ± 1.8
Sugar products & dishes	2.3 ± 7.5	8.5%	225 (27.1)	8.3 ± 12.4
Sugar, honey & syrups	1.2 ± 5.7	4.6%	130 (15.7)	7.7 ± 12.7
Jam & lemon spreads, chocolate spreads, sauces	0.6 ± 2.3	2.4%	101 (12.2)	5.2 ± 4.6
Dishes & products other than confectionery where sugar is the major component	0.4 ± 3.7	1.5%	24 (2.9)	13.9 ± 17.5
Confectionery & cereal/nut/fruit/seed bars	0.9 ± 3.5	3.2%	112 (13.5)	6.3 ± 7.5
Chocolate & chocolate-based confectionery	0.5 ± 2.3	1.8%	57 (6.9)	6.9 ± 5.7
Infant formulae & foods	7.5 ± 10.1	28.4%	769 (92.9)	8.1 ± 10.2
Infant foods	7.0 ± 9.6	26.6%	583 (70.4)	9.9 ± 10.0
Infant foods: Infant custards or yoghurts	4.1 ± 7.0	15.6%	331 (40.0)	10.3 ± 7.7
Infant foods: Infant snack foods[c]	2.8 ± 5.7	10.6%	382 (46.1)	6.0 ± 7.1
Infant drinks[d]	0.3 ± 1.9	1.0%	21 (2.5)	9.9 ± 6.7

[a] Food groups providing <1% contribution to free sugars not listed
[b] Free sugars in fruit products and dishes come only from canned fruit in syrup and stewed fruit with added sugar
[c] New category code created for infant and toddler specific snack foods not part of AUSNUT11-13
[d] Infant drinks category includes infant fruit juices, but does not include infant formula or human breast milk

Factors associated with exceeding the WHO guidelines

Table 4.7 reports factors associated with exceeding the < 5% WHO recommendation for free sugars. Children from families in the lowest household income bracket (≤ \$40,000) had higher odds of exceeding the recommendation compared with families with higher incomes (OR = 2.10; 99% confidence interval [CI] 1.05, 4.20). Similarly, children in the lowest four IRSAD deciles were more likely to exceed the recommendation, when compared with IRSAD ≥5 (OR = 1.94; 99% CI 1.18, 3.18).

Table 4.7 Factors associated with free sugars intakes ≥5% of energy

Variable	Strata	OR	99% CI
Male (vs. Female)	MCOB[a]: Australia or New Zealand	1.96**	[1.13, 3.42]
Male (vs. Female)	MCOB: elsewhere	0.66	[0.23, 1.94]
MCOB[a]: Australia or New Zealand (vs elsewhere)	Female	0.80	[0.34, 1.89]
MCOB: Australia or New Zealand (vs elsewhere)	Male	2.38*	[0.95, 5.96]
MFM[b]: Formula only (vs. any breastfeeding)		1.30	[0.70, 2.40]
MFM: Neither formula nor breastfeeding (vs. any breastfeeding)		1.65*	[0.88, 3.10]
Pre-pregnancy BMI: ≥30 (vs. <30)		0.84	[0.44, 1.59]
Education: High School/Vocational (vs. University)		1.33	[0.78, 2.27]
Household Income: ≤\$40,000 (vs. >\$40,000)		2.10**	[1.05, 4.20]
IRSAD[c] score: 1-4 (vs. 5-10)		1.94***	[1.18, 3.18]
Total number of children: ≥2 (vs. 1)		0.96	[0.59, 1.57]
Mother's Smoking Status: Yes (vs. no)		0.57	[0.21, 1.52]

[a] Mother's Country of Birth
[b] Milk Feeding Method
[c] Index of Relative Socio-economic Advantage and Disadvantage (where 1 = most disadvantaged and 10 = least disadvantaged)
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Among mothers born in Australia or New Zealand (ANZ), sons had twice the odds of exceeding the recommendation compared with daughters (OR = 1.96; 99% CI 1.13, 3.42). There was no such significant difference among mothers not born in ANZ. Stratifying on the child's sex, we found a tendency ($p < 0.05$) of increased odds of exceeding the 5% recommendation among boys with ANZ-born mothers compared with boys with non-ANZ mothers. This tendency is strengthened and significant when we remove participants with implausible intakes (OR = 4.31, 99% CI 1.28, 14.48; supplementary Table 4.10). There was no such difference observed among girls.

Sensitivity analysis

Removal of 129 participants with implausible intakes resulted in similar findings to the whole cohort (supplementary Table 4.9 and supplementary Table 4.10). In this subset, the mean percentage of energy from free sugars was 3.4% (SD 2.5), with 80% of participants consuming less than 5%. The statistically significant factors associated with exceeding the WHO guidelines did not change.

4.3.4 Discussion

Although the Australian Infant Feeding Guidelines recommend that by 12 months of age infants should be consuming a wide variety of family foods (NHMRC, 2012a), little is known about the transitional diet of children, as Australian national dietary surveys do not measure food intakes in children under 2 years of age. To our knowledge, this is the first study to investigate the free sugars intake of Australian children at 12–14 months of age. Although few children in this study exceeded recommended levels of intake of free sugars, findings from cohort studies indicate that diet quality varies greatly at this age (Byrne et al., 2014) and that substantial change occurs between 9 and 18 months of age (Lioret et al., 2013).

Although some children are beginning to consume family foods as they move into the second year of life, many children are already consuming energy-dense, nutrient-poor discretionary foods, which may displace core foods (Byrne et al., 2014; Koh et al., 2010; Lioret et al., 2013). Unsurprisingly, the major food-group contributors to free sugars in our study were similar to the major sources of discretionary foods reported elsewhere (Koh et al., 2010; Lioret et al., 2013).

These findings suggest that although free sugars contribute a lower proportion of energy at 12 months of age than at 2–3 years, behaviours are beginning to emerge that reflect the intake patterns of older children. The major sources of free sugars among 2 to 3 year-olds in the 2011–13 Australian National Nutrition and Physical Activity Survey (NNPAS) were similar to those reported here, including sweet biscuits (8.1% NNPAS, 8.3% here), cakes, muffins, scones and cake-type desserts (9.7% NNPAS, 7.6% here), and yoghurt (6.2% NNPAS, 9.6% here) (ABS, 2016b).

A notable difference to the 12- to 14-month-old children in this study is the apparent non-consumption of commercial infant foods among 2- to 3-year-olds in the NNPAS. It may be that at 2–3 years of age these products are less influential and more family foods are consumed. Alternatively, the infant and toddler food market has grown considerably since the development of AUSNUT2011–13, in terms of both revenue and new product development (IBISWorld Australia, 2017). Toddler foods have recently differentiated from infant foods to form a distinct product line. For example, the Annabel Karmel range that launched in Australia in 2015, in addition to frozen baby purees, includes toddler and children's meals intended for ages up to 5 years (Medianet, 2015). The addition of 187 new infant and toddler foods reported in this study to the limited number of these products in the AUSNUT2011–13 database likely reflects the growing availability and popularity of commercial toddler foods and the possibility of underestimation of these foods in the NNPAS.

A further divergence from the food sources of free sugars among 2 to 3 year-olds in the NNPAS is observed in fruit and vegetable juices and drinks (24.8% NNPAS, 7.4% here). The Australian Infant Feeding Guidelines (NHMRC, 2012a) advise that fruit juice drinks are not necessary or recommended for infants under 12 months, and the modest number of consumers (n = 101, 12%) in this study suggest that parents are complying with this recommendation. Among consumers, this food group was the second highest contributor of free sugars. It appears that these drinks are introduced in the second and third years of life, as children continue to transition to family foods and milk consumption declines. A recent Australian study observed a decline in milk-based drinks accompanied by an increase in sugar-sweetened beverages, particularly fruit juice-based drinks, between the ages of 2–5 years (Byrne et al., 2018).

We found that sons of Australian born mothers were twice as likely to exceed the WHO < 5% recommendation than daughters. Dietary studies frequently adjust for sex due to the higher total energy intakes of boys than girls, and there is limited reporting on gender discrepancies. Among older children, gender differences have been reported in energy-adjusted consumption of core food groups; however, studies are limited, and findings are inconsistent (Dubois et al., 2011; Glynn et al., 2005;

Jones et al., 2010). Further research is needed to investigate whether ours is a replicable finding, which may be attributed to sociocultural differences in perceptions of boys and girls. There is evidence that gendered food habits persist among adults (McPhail et al., 2012), that gendered body ideals are internalised from a young age (Damiano et al., 2015), and that parental eating psychopathology can result in gendered feeding behaviours, in particular by mothers towards their daughters (McPhie et al., 2014).

Food preferences and eating habits established early in life can track into childhood and beyond (Nicklaus, 2009; Scott et al., 2012) and early nutrition can influence susceptibility to obesity and other metabolic outcomes in later life (Lillycrop & Burdge, 2011; Strazzullo et al., 2012). There is evidence that infants are born with a predisposition for sweet and probably salty tastes (Mennella, 2014), both of which are frequently associated with energy-dense, nutrient-poor foods. This biological drive is thought to have helped infants achieve adequate growth in times of energy scarcity, and may still be an important factor for early growth (Drewnowski et al., 2012). However, this innate sweet preference appears to decline throughout childhood, whereas dietary experiences through early childhood shape later preferences and taste expectations around the sweetness of the food supply (Drewnowski et al., 2012). Lioret et al. (2013) found that for many core and non-core foods, being a consumer or consuming larger amounts at 9 months of age were both predictive of a greater level of consumption of the same foods at 18 months of age. Byrne et al. (2018) reported strong correlations in tracking of sweet drinks from 2 to 5 years of age. The effects of exposure to sugar on the development of food and flavour preferences may be greatest when complementary foods are being introduced. Hence, the weaning period has been identified “as an opportune time to promote the acceptance of foods that are characteristic of healthy diets” (Birch & Doub, 2014, p. 723s). It is particularly important that young children do not exceed the WHO recommendations for free sugars intakes when these early taste preferences are being formed.

High levels of total and added sugars have been reported in commercial ready-to-feed infant and toddler foods in the United States (Maalouf et al., 2017), Canada (Elliott, 2011), and the United Kingdom (García et al., 2013). A review of the Australian commercial infant food market found lower levels of added sugars compared with the United Kingdom and Canadian studies, but comparably high total sugars values, noting the presence of fruit as sweeteners in Australian products (Dunford et al., 2015).

The Australia New Zealand Food Standards code provides limited regulation regarding the composition and labelling of commercial infant foods in Standard 2.9.2 (Australian Government, 2017b). Free sugars are not mentioned at all, and the code defines an infant as a person under 12 months of age, so toddler products labelled for 12 months and older are not covered by this standard. Infant foods containing more than 4 g/100 g added sugars must be labelled as "sweetened"; however use of the term "added sugars" allows manufacturers to subvert the standard by sweetening products with fruit juice or fruit juice concentrate. These products are often labelled "no added sugar" to appeal to parents' desire to provide healthy foods. Given the proliferation in the number and sales of toddler foods in recent years, the current standard should be extended, or a new standard developed, to cover toddler foods and incorporate the definition of free sugars.

These findings support the existing evidence that dietary behaviours are influenced by social determinants, with poorer adherence to dietary recommendations reported among those with greater socio-economic disadvantage (Cameron et al., 2012; Darmon & Drewnowski, 2008). This disadvantage is also seen in access to dental services, with more people in lower household income groups avoiding or delaying a visit to the dentist due to cost compared with those in higher income groups (Australian Institute of Health and Welfare, 2015). The possible compounding effect of higher free sugars intakes and lower access to dental services may explain some of the disparity in caries experience, and the interaction pathways between socio-economic disadvantage and oral health in the SMILE cohort are an ongoing area of investigation (Do et al., 2014).

Determination of free sugars from Australian dietary data has only recently been possible, as AUSNUT2011–13 is the first national nutrient database to include values for added and free sugars. There are no analytical measures for determining free sugars separately to total sugars, as the definition relates to food source rather than any molecular difference between the types of sugars. A modified 10-step methodology is used to determine the contribution of free sugars (Louie et al., 2015) The earliest methodology steps are associated with greatest confidence and move from objective to subjective at step 7. For AUSNUT2011–13, only Steps 1–4 were necessary as there is a corresponding recipe database to accompany AUSNUT that was used to handle all foods that contained a combination of free and intrinsic sugars (FSANZ, 2016). Within our study, where an infant food product was added to the database, we used up to the full 10-step methodology to determine free sugars as product recipes were not available. Free sugars values for these additional foods may therefore be less accurate than those provided in the AUSNUT2011–13 database.

The AUSNUT2011–13 database is limited by the food products available during the update period. The Australian food supply is ever-changing and nutrient database updates are infrequent. In particular, the infant formula and foods category contains only a few crude groups that do not reflect the current infant and toddler market. In addition, AUSNUT2011–13 classifies all infant and toddler formula as lacking free sugars despite the presence of sucrose in the ingredients list of soy-based formula.

In our study, the WHO (2015) conditional recommendation of less than 5% energy from free sugars was used as the outcome variable due to relatively low numbers of participants exceeding the 10% recommendation. This conservative recommendation may be the more appropriate target for 12–14 month olds, given the early establishment of taste preferences, the increasing intakes of energy-dense, nutrient-poor foods through childhood, and the cumulative effect of dental caries, which tracks from childhood to adulthood (WHO, 2015). This also reflects the recommendations of the Australian Infant Feeding Guidelines (NHMRC, 2012a)to limit or avoid foods with added sugars in the first 12 months of life, and that no sugar should be added to foods prepared for infants. The current evidence for the 5% recommendation was rated as very low quality, based on older children only, and is an area of ongoing investigation at all ages (Moynihan & Kelly, 2014).

A strength of this study is our dietary data collection methods. The use of a 24-hr recall and 2-day food record resulted in 3 non-consecutive days of data, which included two weekdays and one weekend day. The phone interview 24-hour recall allowed researchers to issue instructions for the food record and provide basic training to participants in the use of the reference images and level of detail required. Participants could ask questions to ensure they understood what was required in the food record. The effectiveness of this method is demonstrated by the fact that out of the 847 food records that were returned, only 12 were excluded due to poor quality. We coupled this with standardisation protocols at data entry, and every participant's data were double-entered to reduce error. In addition, the Multiple Source Method (Harttig et al., 2011) allowed us to adjust for day-to-day variability in order to determine usual intake of free sugars, rather than averaging the 3 days. Nevertheless, dietary assessment is by nature limited in terms of precision and accuracy. Due to the age of participants, proxy reporting by the mothers was necessary, which may not describe the complete food landscape experienced by the child. Social desirability bias may have influenced reports given by mothers, and other forms of misreporting are likely to have been present (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). Study non-responders were not significantly different from responders across most socio-demographic variables, with the age of the mothers and some countries of birth the only notable differences. As such, the findings here are considered generalizable to the sampling population.

4.3.5 Conclusion

Our analysis found that the diets of more than four out of every five children aged 12 to 14 months comply with the WHO 5% recommendation, and almost all comply with the 10% recommendation. Children who experienced greater socio-economic disadvantage were more likely to exceed the recommendations, indicating that efforts to increase compliance should be targeted towards these groups. The major food sources of free sugars at this age were similar to the major sources later in life, suggesting that the establishment of dietary patterns commences from the beginning of solid food introduction. An additional finding was the substantial contribution to free sugars by products promoted as infant and toddler foods, many of which contain fruit juice to subvert food labelling requirements for added sugars. These findings emphasise the importance of dietary intervention and education from the commencement of weaning, including specific advice around selecting appropriate foods within the infant and toddler food market. Future policy decisions around food labelling should consider the different definitions of added and free sugars in providing information that best serves the consumer. In the absence of action by food manufacturers, policymakers should consider regulation to limit the amount of free sugars in commercial infant and toddler foods. At the very least, food standards related to added sugars in infant foods should be extended to include toddler foods.

Acknowledgments: This research is part of the Study of Mothers' and Infants' Life Events affecting oral health. We acknowledge Dr Diep Ha for co-ordination of the SMILE recruitment and data collection procedures, along with the wider SMILE research team. Thanks also to Ms Elizabeth Beaton for assisting with secondary entry of dietary data. The authors would like to acknowledge the Australian Government Research Training Program Scholarship in supporting this research.

Conflicts of Interest: The authors declare that they have no conflicts of interest

Contributions: LD and JS conceived and designed the study, secured funding, and coordinated the research team; GD helped design and administer the dietary assessment components, assisted with statistical analysis, and prepared the manuscript in consultation with all authors; AB assisted with study design; EY performed the statistical analysis. All authors were involved in interpreting the results and preparation of the manuscript.

4.3.6 Supplementary materials

Three supplementary materials are provided with this publication. Table 4.8 presents characteristics by response status and compliance with the WHO recommendations for free sugars intakes. An enlarged version of this table is provided in Appendix H. The sensitivity analysis is reported in Table 4.9 and Table 4.10. These tables reflect the main results tables, reanalysed with only those participants identified as having plausible energy intakes included. Methods were described in 4.3.2, and results briefly reported in 4.3.3.

Table 4.8 Participant characteristics

	Non-Respondents			Respondents			Respondents with Free Sugars <5% of Energy			Respondents with Free Sugars ≥5% of Energy			Respondents with Free Sugars ≥10% of Energy		
	n	mean	SD	n	mean	SD	n	mean	SD	n	mean	SD	n	mean	SD
Mother's age at birth (years)	1275	29.2	5.6	826	30.8	4.9	637	31	4.8	189	30	5.3	20	28.1	6.9
Total number of children	1066	1.9	1	801	1.7	0.9	615	1.7	0.8	186	1.8	1	20	2	1.2
Child's birthweight (g)	1265	3328.4	578.6	818	3397.9	558.1	632	3396.5	571.1	186	3402.6	513	20	3370.8	428.5
Child's age at 24HR (months)	0			807	13.1	0.8	625	13.1	0.8	182	13.2	0.9	20	13.1	0.9
	n	%		n	%		n	%		n	%		n	%	
Child's sex															
Male	694	51.5		452	54.6		335	52.4		117	61.9		12	60	
Female	653	48.5		376	45.4		304	47.6		72	38.1		8	40	
Milk Feeding method															
Breastfeeding only	NA			220	26.6		181	28.3		39	20.6		5	25.0	
Breastfeeding and Formula	NA			68	8.2		57	8.9		11	5.8		0	0	
Formula only	NA			310	37.4		235	36.8		75	39.7		7	35.0	
Neither	NA			230	27.8		166	26		64	33.9		8	40.0	
Mother's pre-pregnancy BMI[a] (kg/m^2)															
<18.5	57	5		41	5.2		36	5.9		5	2.9		0	0	
18.5-24.99	552	48		436	55.6		343	56		93	54.1		10	55.6	
25-29.99	288	25.1		167	21.3		126	20.6		41	23.8		2	11.1	
≥30	252	21.9		140	17.9		107	17.5		33	19.2		6	33.3	
Mother's smoking status at 12months															
no	419	90.5		746	92		576	92.2		170	91.4		16	80	
yes	44	9.5		65	8		49	7.8		16	8.6		4	20	
Total number of children															
1	474	44.5		389	48.6		299	48.6		90	48.4		11	55	
2	379	35.6		291	36.3		229	37.2		62	33.3		3	15	
≥3	213	20		121	15.1		87	14.1		34	18.3		6	30	
Mother's Education															
some high school	228	17.8		61	7.4		38	6		23	12.3		4	20	
completed high school	192	15		83	10.1		53	8.3		30	16		4	20	
some vocational training	80	6.2		36	4.4		26	4.1		10	5.3		3	15	
completed vocational training	280	21.9		176	21.4		137	21.5		39	20.9		5	25	
some university or college	75	5.9		85	10.3		64	10		21	11.2		1	5	
completed university or college	269	21		246	29.9		200	31.4		46	24.6		3	15	
postgraduate	156	12.2		137	16.6		119	18.7		18	9.6		0	0	
Household Income ($)															
≤40,000	299	25.1		92	11.5		57	9.3		35	19		9	45	
40,001-80,000	429	36		254	31.8		192	31.3		62	33.7		7	35	
80,001-120,000	295	24.7		254	31.8		199	32.4		55	29.9		4	20	
≥120,000	170	14.2		198	24.8		166	27		32	17.4		0	0	
IRSAD[b]															
Deciles 1-2	342	27.2		120	14.6		83	13.1		37	19.6		3	15	
Deciles 3-4	273	21.7		173	21		118	18.6		55	29.1		7	35	
Deciles 5-6	216	17.2		174	21.2		144	22.7		30	15.9		1	5	
Deciles 7-8	225	17.9		160	19.5		133	21		27	14.3		3	15	
Deciles 9-10	203	16.1		195	23.7		155	24.5		40	21.2		6	30	
Mother's Country of Birth															
Australia or New Zealand	843	66.2		610	74.1		459	72.4		151	79.9		17	85	
United Kingdom	46	3.6		31	3.8		23	3.6		8	4.2		2	10	
India	136	10.7		50	6.1		38	6		12	6.3		0	0	
China	28	2.2		37	4.5		37	5.8		0	0		0	0	
Asia-other	123	9.7		52	6.3		45	7.1		7	3.7		0	0	
Other	98	7.7		43	5.2		32	5		11	5.8		1	5	

[a] Body Mass Index (kg/m^2, where <18.5 = underweight; 18.5-24.99 = healthy weight range; 25-29.99 = overweight; ≥30 = obese)
[b] Index of Relative Socio-economic Advantage and Disadvantage (where 1 = most disadvantaged and 10 = least disadvantaged)
NA = data not available

(see Appendix H for enlarged version)

Table 4.9 Free sugars at 12 months: participants with plausible intakes (*n* = 699)

	Mean ± SD	Range	Percentile 25th, 75th
Free Sugars (g/day)	7.8 ± 5.8	0.24 – 42.3	3.5, 10.2
Total Sugars (g/day)	62.0 ± 14.8	19.2 – 109.6	51.8, 71.3
Energy (kJ/day)	3779 ± 567	2240 – 5160	3393, 4216
%En from Free Sugars	3.4 ± 2.5	0.10 – 18.0	1.6, 4.6
	n	**%**	
<5%Energy from Free Sugars	559	80.0	
≥5%Energy from Free Sugars	140	20.0	
≥10%Energy from Free Sugars	14	2.0	

Table 4.10 Factors associated with free sugars intakes ≥5% of energy: participants with plausible intakes (*n* = 699)

Variable	Strata	OR	99% CI
Male (vs. Female)	MCOB[a]: Australia or New Zealand	1.95**	[1.04, 3.63]
Male (vs. Female)	MCOB: elsewhere	0.54	[0.13, 2.19]
MCOB[a]: Australia or New Zealand (vs elsewhere)	Female	1.18	[0.42, 3.34]
MCOB: Australia or New Zealand (vs elsewhere)	Male	4.31*	[1.28, 14.48]
MFM[b]: Formula only (vs. any breastfeeding)		1.45	[0.73, 2.90]
MFM: Neither formula nor breastfeeding (vs. any breastfeeding)		1.35*	[0.64, 2.82]
Pre-pregnancy BMI: ≥30 (vs. <30)		0.76	[0.36, 1.59]
Education: High School/Vocational (vs. University)		1.48	[0.80, 2.74]
Household Income: ≤$40,000 (vs. >$40,000)		2.57**	[1.20, 5.50]
IRSAD[c] score: 1-4 (vs. 5-10)		1.90***	[1.08, 3.34]
Total number of children: ≥2 (vs. 1)		0.93	[0.53, 1.62]
Mother's Smoking Status: Yes (vs. no)		0.60	[0.21, 1.71]

[a] Mother's Country of Birth

[b] Milk Feeding Method

[c] Index of Relative Socio-economic Advantage and Disadvantage (where 1 = most disadvantaged and 10 = least disadvantaged)

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

4.4 Original Research: Free Sugars Intake, Sources and Determinants of High Consumption among Australian 2-Year-Olds in the SMILE Cohort

Abstract: In the first 2 years of life, it is important to limit exposure to foods high in free sugars, in order to lay foundations for lifelong eating patterns associated with a reduced risk of chronic disease. Intake data at this age is limited, so compliance with recommendations is not known. This analysis describes free sugars intakes, food sources and determinants of high consumption among Australian children at 2 years of age. Free sugars intakes were estimated using a customised food frequency questionnaire, and median usual free sugars intake at 2 years was 22.5 (Interquartile Range (IQR) 12.8–37.7) g/day, contributing a median 8% of the estimated energy requirement (EER). Based on the EER, most children (71.1%) exceeded the World Health Organization recommendation that less than 5% of energy should come from free sugars, with 38% of participants exceeding the less than 10% recommendation. Children from households with the greatest socio-economic disadvantage were more likely to exceed the 10% recommendation (Prevalence Ratio (PR) 1.44, 95% Confidence Interval (95%CI) 1.13–1.84), and be in the top tertile for free sugars intake (PR 1.58, 95%CI 1.19–2.10) than the least disadvantaged. Main sources of free sugars were non-core foods, such as fruit juice, biscuits, cakes, desserts and confectionery; with yoghurt and non-dairy milk alternatives the two notable exceptions. Improved efforts to reduce free sugars are needed from the introduction of solid food, with a particular focus on fruit juice and non-core foods.

Keywords: free sugars; food frequency questionnaire; dietary intakes; 24-h recall; 2-day food record; food sources; socio-demographic determinants; early childhood; complementary feeding.

4.4.1 Introduction

The first 2 years of life is a critical time for establishing food preferences and eating behaviours that lay the foundations for long-term dietary habits (Birch & Doub, 2014; Nicklaus, 2009). It is important that during this time children are exposed to a wide variety of nutritious foods, with limited intakes of foods higher in saturated fat, added salt and added sugars (NHMRC, 2012a, 2013). The recommendations of the

WHO (2015) to limit free sugars to less than 10%, and ideally less than 5% of energy intake, are particularly relevant during the early years while taste preferences are being established (Drewnowski et al., 2012; Mennella, 2014). The WHO (2015, p. 4) defines free sugars as “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”. Consumption of free sugars above these recommendations is associated with increased body weight and dental caries from early childhood through to adulthood (WHO, 2015). When introducing solids it is important to limit exposure to foods and drinks high in free sugars, in order to establish lifelong healthy eating patterns (Mennella, 2014; NHMRC, 2012a).

The Australian National Nutrition and Physical Activity Survey (NNPAS) reported an increasing trend in free sugars intakes from 2–3 years of age throughout childhood, peaking in adolescence and then declining gradually through adulthood (ABS, 2016b). This was the first national survey to report free sugars intakes, supported by an updated Australian nutrient database (AUSNUT2011–13), which includes values for added and free sugars for the first time (FSANZ, 2016). Just over 50% of children aged 2–3 years in the NNPAS exceeded the WHO recommendation that less than 10% of total energy should come from free sugars, and 93% exceeded the less than 5% recommendation (ABS, 2016b). Unsurprisingly, most free sugars came from non-core foods and beverages, accounting for 81% of free sugars intakes across all ages (ABS, 2016b).

At present, national nutrition monitoring does not collect data for children less than 2 years of age, so knowledge of dietary intakes as children transition to the family diet is limited. Recent Australian studies around this age raise concerns around early exposure to non-core foods (Amezdroz et al., 2015; Byrne et al., 2014; Byrne et al., 2018; Koh et al., 2010), inadequate fruit and vegetable consumption (Bell et al., 2016a), inadequate iron intake (Atkins et al., 2016; Conn et al., 2009; Scott et al., 2016; Webb et al., 2008), and poor overall compliance with dietary guidelines (Spence et al., 2018). Findings also suggest that dietary behaviours track over time, emphasising the importance of establishing healthy food patterns from an early age (Amezdroz et al., 2015; Byrne et al., 2014; Byrne et al., 2018; Spence et al., 2018). Some of these studies have investigated determinants, and report associations between socio-economic factors and diet quality (Bell et al., 2016a; Cameron et al., 2012; Chung et al., 2018; Spence et al., 2018). None of these studies report free sugars intakes.

In the first few months of life, intakes of free sugars are likely to be minimal, as breast milk and the majority of animal milk-based infant formula do not contain free sugars. At present, little is known about when and in what forms free sugars enter the diet, as children move through the weaning period towards a dietary pattern reflective of their family's diet. Free sugars intakes at 1 year of age have recently been reported for participants in the Study of Mothers' and Infants' Life Events affecting oral health (Devenish et al., 2019b). This research extends this work to report findings for the same cohort at 2 years of age.

The primary aims of this study are to describe free sugars intakes and food sources among Australian children at 2 years of age, and investigate socio-demographic determinants of high free sugars consumption. Secondary aims are to determine compliance at 2 years with the WHO (2015) guideline for sugars intake for adults and children; and to examine tracking of free sugars intake between 1–2 years of age.

4.4.2 Materials and Methods

Recruitment and data source

Data came from the Study of Mothers' and Infants' Life Events affecting oral health (SMILE). This birth cohort consisted of 2147 mothers and 2181 children, including 34 sets of twins, recruited from the major maternity hospitals in Adelaide from July 2013 to August 2014. Study methods, including sampling, recruitment and data collection, are described in detail elsewhere (Do et al., 2014). All new mothers with sufficient English competency and not intending to move out of the greater Adelaide area within a year were invited to participate. Women from hospitals in lower socio-economic areas were oversampled to account for higher attrition rates, which resulted in a cohort that was generally representative of the socio-economic profile reported by the Pregnancy Outcome unit for South Australian births in 2013 (Scheil et al., 2015). Data were collected at baseline and when the child was three, six, twelve and twenty-four months of age. A range of dietary, dental and socio-demographic risk factors were captured, via the parents' choice of online, paper or telephone questionnaire (Do et al., 2014). The Southern Adelaide Clinical Human Research Ethics Committee approved the study (HREC/50.13, approval date: 28 Feb 2013) as did the South Australian Women and Children Health Network (HREC/13/WCHN/69, approval date: 7 Aug 2013).

Dietary intake data

Dietary data used in this analysis were collected using a customised 89-item, semi-quantitative Food Frequency Questionnaire (SMILE-FFQ) emailed or posted to parents when their child reached 2 years of age. At this time they were also invited to book their child in for a dental examination with the SMILE team. In addition to the dental assessment at this appointment, the child's weight and standing height were measured by a trained member of the SMILE team, using calibrated equipment and following standardised methodology (WHO, 1995).

The SMILE-FFQ was designed to estimate usual intake of total and free sugars in Australian toddlers and was validated against repeat 24-hour recalls in an external cohort (Devenish et al., 2017). A matching database customised for the SMILE-FFQ was linked to responses using Microsoft Access version 15 (Microsoft Corporation, 2013, Washington, DC, USA) to generate an estimated usual intake of total and free sugars. Free sugars values for each line item in the FFQ were determined by adapting the method by Louie et al. (2015), to incorporate the WHO (2015) definition of free sugars.

As the SMILE-FFQ was not designed to capture total energy intake, it was not possible to determine the percentage of energy intake from free sugars at 2 years of age. As an alternative, Estimated Energy Requirement (EER) was determined from age and weight data, and used to calculate percentage of EER from free sugars. The method for calculating EER used in the Australian Nutrient Reference Values (NHMRC, 2006) was followed, using an equation for children aged 13–35 months that was developed by the Food and Nutrition Board of the Institute of Medicine (2006). Participants with no weight measurement who returned a complete FFQ (n = 125) were assigned a reference EER using the Nutrient Reference Value for age and gender (NHMRC, 2006). Sensitivity analysis was conducted by repeating the primary analyses with these participants removed.

For the food group analysis, each line item in the SMILE-FFQ was linked to a food group from the AUSNUT2011–13 database, mostly at the sub-major food group level. The groups 'Fruit products and dishes' and 'Snack foods' were linked at the major food group level only, as the line items in the FFQ related to these broader categories. Conversely, the AUSNUT2011–13 sub-major group 'Infant formula and foods' was too broad, so these items were further broken down into minor food groups. Out of the 132 sub-major food groups in the AUSNUT2011–13 database; 55 were linked to at least one item in the FFQ. Those that were not represented were either foods not commonly consumed by pre-school aged children (e.g., alcohol and coffee) or foods low in sugars (e.g., meat, eggs, vegetables etc.).

Dietary collection methods at 1 year, along with findings for free sugars intakes, food groups and determinants are reported in detail elsewhere (Devenish et al., 2019b). Briefly, after the child's first birthday, 3 non-consecutive days of dietary data were obtained via a 24-hour recall and 2-day food diary, following standardised methods and protocols (ABS, 2014b; Thompson & Subar, 2013) that were tailored to this age. Data were entered into FoodWorks version 8 (Xyris Software, 2012–2017, Brisbane, Australia) and analysed with the current Australian food composition database, AUSNUT2011–13 (FSANZ, 2014), supplemented with additional infant and toddler food items that were lacking in the national database. The Multiple Source Method (Harttig et al., 2011) was applied to the resulting three days of dietary data to obtain the usual daily intake of total sugars, free sugars and energy for each child, and the percentage of energy from free sugars was calculated.

Socio-demographic data

Socio-demographic data collected via self-report questionnaire at recruitment were used to generate the following categorical explanatory variables for the determinant analysis: Mother's age at baseline ('< 25', '25 – 34' and '≥ 35' years); Mother's pre-pregnancy weight status using Body Mass Index (BMI) (WHO, 2000) ('< 25', '25 – 29.99' and '≥ 30' kg/m^2); Mother's country of birth ('Australia and New Zealand' and 'Other'); Mother's education ('high school/vocational', and 'some university and above'); total number of children ('1', '2' and '≥ 3') and infant sex ('male' and 'female'). Postcode was used to derive a measure of socio-economic status using the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD), which was grouped into five decile pairs (ABS, 2013).

Statistical methods

Participants with nutrient intakes ≥ 3 standard deviations from the mean for free sugars at either time point, or energy intakes at 1 year, were considered extreme misreporters and excluded from that time point (Atkins et al., 2016). This excluded a total of 25 participants from the 1 year (n = 11), 2 year (n = 13) or both (n = 1) datasets. Characteristics of participants with plausible and complete dietary data and those without were compared using the Pearson Chi Square test for categorical variables and the independent samples t-test for continuous variables.

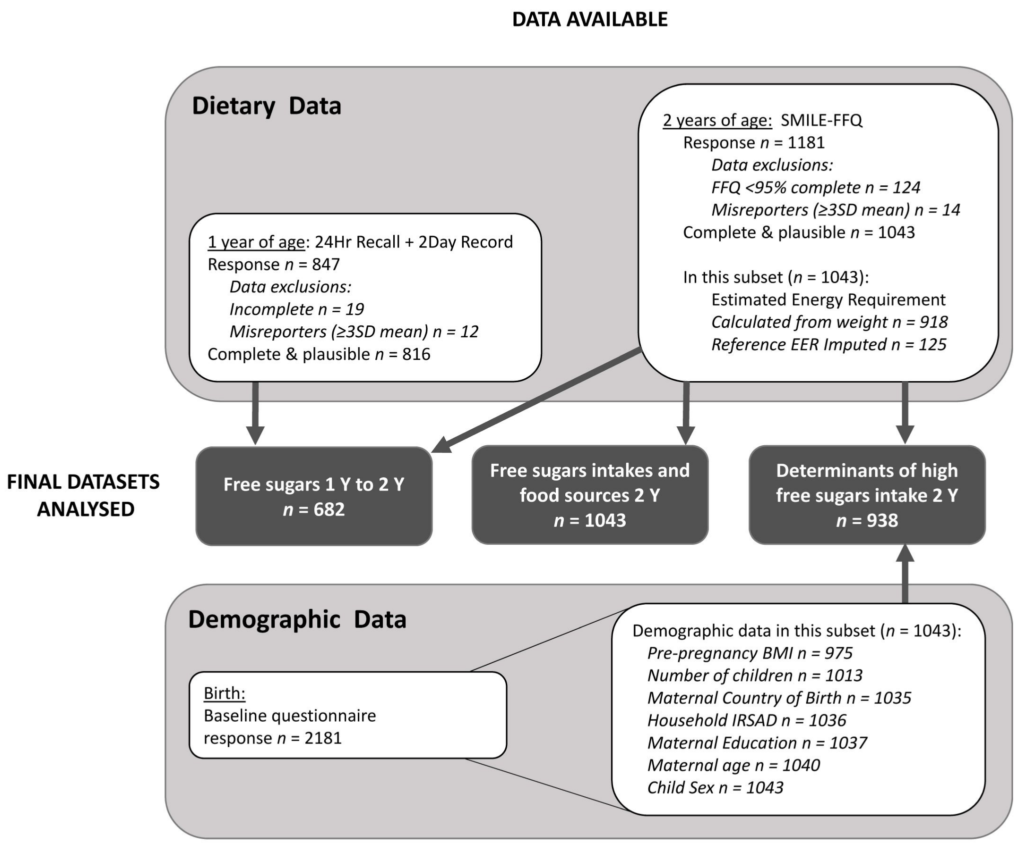
Nutrient intake distributions were right-skewed so nonparametric methods (median, interquartile range) were used to describe nutrient intakes and percentage of EER from free sugars. The percentage of children with free sugars intakes ≥ 5% and ≥ 10% of EER are also reported.

For the food group contributions at 2 years, the mean free sugars (g) for each food group were calculated for all participants and consumers only, at the major and sub-major food group levels, and the minor food group level for infant foods. Consumers were defined as those who reported any valid response other than "never or rarely" in the SMILE-FFQ, for at least one line item within each food group.

Due to the different dietary assessment methods at the two time points, statistical comparisons of free sugars intakes at 1 and 2 years focused on movement relative to the cohort, rather than absolute values. Participants were ranked into tertiles of free sugars consumption at 1 and 2 years of age, and movement between tertiles was compared using crosstabulations and the Weighted Kappa test. SPSS version 25 was used for these analyses (IBM SPSS Statistics for Windows, New York, NY, USA), with statistical significance set at $p < 0.05$.

Socio-demographic factors identified in the literature as being associated with poor diet quality in early childhood were investigated as determinants of high free sugars intakes with generalized regression models, using a log-binomial link function in SAS PROC GENMOD (SAS Institute Inc., Cary, NC, USA). The outcome variables were the highest free sugars tertile at 2 years, and free sugars intakes ≥ 10% of EER at 2 years. The models estimated adjusted prevalence ratios (PRs) and associated 95% confidence intervals (CI). Participants with data missing for one or more of the explanatory variables (n = 105, 10%) were excluded from this analysis (Figure 4.3). An interaction between mother's country of birth, child's sex and free sugars intake observed in the SMILE cohort at 1 year of age (Devenish et al., 2019b) was investigated with the 2 year dietary data. However, preliminary analysis revealed that this interaction was not significant at 2 years, and so was not included in the models for this study.

Figure 4.3 Participant flowchart for the analysis datasets



SMILE-FFQ: Study of Mothers and Infants Life Events Food Frequency Questionnaire, SD: Standard Deviation; Y: year; BMI: Body Mass Index; IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.

4.4.3 Results

Participants

Figure 4.3 depicts participant flow for the analysis datasets. There were 1043 participants with plausible and complete 2 year dietary data that were included in descriptive and food group analysis. Table 4.11 compares characteristics of these participants to non-responders. Plausible and complete 1 year dietary data were available for 816 participants, of whom 682 also provided data at 2 years for comparison. Participant characteristics of this sub-set are presented in Table 4.16.

Table 4.11 Participant characteristics

	All Participants (*n* = 2181)			**Responders 2 Years (*n* = 1043)**			**Non-Responders 2 Years (*n* = 1138)**			***p*** [a]
	n	**mean**	**SD**	***n***	**mean**	**SD**	***n***	**mean**	**SD**	
Mother's age at birth (years)	2101	29.9	5.4	1040	30.6	5.0	1061	29.2	5.7	<0.001
Total number of children	1867	1.8	1.0	1013	1.8	0.9	854	1.9	1.0	0.012
Child's birthweight (g)	2083	3356	572	1032	3393	547	1051	3319	593	0.003
	n	**%**		***n***	**%**		***n***	**%**		
Mother's age at birth (years)										<0.001
<25	336	16.0		105	10.1		231	21.8		
25–34.99	1353	64.4		717	68.9		636	59.9		
≥35	412	19.6		218	21.0		194	18.3		
Mother's pre-pregnancy BMI (kg/m^2)										0.274
<25	1086	56.2		565	57.9		521	54.4		
25–29.99 (overweight)	455	23.5		218	22.4		237	24.7		
≥30 (obese)	392	20.3		192	19.7		200	20.9		
Mother's Country of Birth										<0.001
Australia or New Zealand	1453	69.3		755	72.9		698	65.7		
Other	644	30.7		280	27.1		364	34.3		
Mother's Education										<0.001
high school/vocational	1136	54.0		451	43.5		685	64.2		
some university and above	968	46.0		586	56.5		382	35.8		
IRSAD										<0.001
Deciles 1–2 (most disadvantaged)	462	22.2		172	16.6		290	27.8		
Deciles 3–4	446	21.4		214	20.7		232	22.2		
Deciles 5–6	390	18.7		210	20.3		180	17.2		
Deciles 7–8	385	18.5		199	19.2		186	17.8		
Deciles 9–10 (most advantaged)	398	19.1		241	23.3		157	15.0		
Total number of children										0.111
1	863	46.2		480	47.4		383	44.8		
2	670	35.9		369	36.4		301	35.2		
≥3	334	17.9		164	16.2		170	19.9		
Child's sex										0.579
Male	1146	52.7		556	53.3		590	52.1		
Female	1029	47.3		487	46.7		542	47.9		

[a] *p* values for responders v non-responders at 2 years using t-test (continuous) or Pearson Chi Square test (categorical).

BMI: Body Mass Index. IRSAD: Index of Relative Socio-economic Advantage and Disadvantage. SD: Standard Deviation

Free sugars intakes at 2 years of age

Median free sugars intake at 2 years of age was 22.5 (IQR 12.8–37.7) grams per day, providing a median 8% of EER (Table 4.12). Mean intake was 29.3 (SD 23.7) grams per day, providing a mean 10.4 (SD 8.6) percent of EER. For most (71.1%) of the children in this cohort, free sugars intake exceeded 5% of their EER, with 38.4% of children exceeding 10% of EER.

Table 4.12 Free sugars intakes at 2 years of age (*n* = 1043)

		Percentile		
	Median	**25th**	**75th**	**Range**
Free Sugars (g/day)	22.5	12.8	37.7	0.3–140.7
Tertile 1 (low)	10.6	7.4	13.0	0.3–15.8
Tertile 2 (mid)	22.7	19.0	26.4	15.81–31.6
Tertile 3 (high)	47.2	38.0	66.7	31.61–140.7
Total Sugars (g/day)	77.5	56.0	105.3	9.4–294.8
Estimated Energy Requirement (kJ/day)	4730	4357	5214	2644–8193
Percentage of Estimated Energy Requirement from Free Sugars (%)	8.0	4.6	13.2	0.1–61.3

Food group contribution to free sugars intakes

Table 4.13 provides a breakdown of food group contribution to free sugars intake by major and sub-major food groups among all participants and consumers only. At the major food group level, cereal-based products and dishes (19% of free sugars), non-alcoholic beverages (16%), milk products and dishes (16%), infant formula and foods (15%), sugar products and dishes (12%) and confectionery and cereal nut/fruit/seed bars (9%) were key contributors to free sugars.

Drilling down to the sub-major food groups, the greatest overall contribution to free sugars came from fruit and vegetable juices and drinks (11%), followed by infant custards and yoghurts (10%) and yoghurts that were not specifically identified for infants (9%). The next highest contributors were cakes, muffins, doughnuts and cake-type desserts (8%), and sweet biscuits (7%), followed by sugar, honey and syrups (5%) and chocolate based confectionery (5%).

Table 4.13 Food group contributions to free sugars intakes at 2 years of age

Food group [a]	All Participants (n = 1043)		Consumers	
	mean ± SD free sugars (g)	% contribution to free sugars	*n* (%)	mean ± SD free sugars (g)
Non-alcoholic beverages	4.7 ± 9.7	15.9	1037 (99.4)	4.7 ± 9.7
Fruit & vegetable juices, & drinks	3.1 ± 7.3	10.7	590 (56.6)	5.5 ± 9.0
Cordials	0.8 ± 3.8	2.6	179 (17.2)	4.5 ± 8.4
Soft drinks, flavoured mineral waters	0.2 ± 1.3	0.8	147 (14.1)	1.7 ± 3.1
Other beverage flavourings	0.3 ± 1.7	0.9	246 (23.6)	1.2 ± 3.5
Cereals & cereal products	1.1 ± 2.1	3.7	953 (91.4)	1.2 ± 2.1
Breakfast cereals, ready to eat	1.1 ± 2.1	3.7	884 (84.8)	1.3 ± 2.2
Cereal based products & dishes	5.5 ± 6.9	18.8	1028 (98.6)	5.6 ± 6.9
Sweet biscuits	2.2 ± 3.5	7.4	908 (87.1)	2.5 ± 3.6
Savoury biscuits	0.3 ± 0.5	0.9	947 (90.8)	0.3 ± 0.5
Cakes, muffins, doughnuts, cake-type desserts [b]	2.2 ± 4.2	7.5	674 (64.6)	3.4 ± 4.8
Batter-based products, scones, sweet breads [b]	0.8 ± 1.6	2.6	468 (44.9)	1.7 ± 2.0
Fruit products & dishes [c]	0.3 ± 1.2	1.2	1029 (98.7)	0.3 ± 1.2
Milk products & dishes	4.8 ± 7.1	16.4	1015 (97.3)	4.9 ± 7.2
Yoghurt	2.6 ± 5.2	8.8	787 (75.5)	3.4 ± 5.8
Frozen milk products	0.9 ± 1.9	3.1	605 (58.0)	1.5 ± 2.2
Custards	0.9 ± 3.3	2.9	325 (31.2)	2.8 ± 5.5
Flavoured milks & milkshakes	0.4 ± 1.5	1.2	211 (20.2)	1.8 ± 3.0
Dairy & meat substitutes	1.7 ± 4.9	5.8	438 (42.0)	4.0 ± 6.9
Dairy milk substitutes, unflavoured	1.2 ± 3.8	4.2	245 (23.5)	5.2 ± 6.5
Savoury sauces & condiments	0.5 ± 1.0	1.8	792 (75.9)	0.7 ± 1.2
Gravies & savoury sauces	0.5 ± 0.9	1.6	758 (72.7)	0.6 ± 1.0
Sugar products & dishes	3.4 ± 5.7	11.7	846 (81.1)	4.2 ± 6.0
Sugar, honey & syrups	1.5 ± 3.5	5.1	609 (58.4)	2.6 ± 4.3
Jam & lemon spreads, chocolate spreads, sauces	1.0 ± 2.7	3.3	541 (51.9)	1.8 ± 3.5
Dishes & products other than confectionery where sugar is the major component	1.0 ± 2.8	3.3	450 (43.1)	2.2 ± 3.9
Confectionery, cereal/nut/fruit/seed bars	2.8 ± 3.9	9.4	871 (83.5)	3.3 ± 4.0
Chocolate & chocolate-based confectionery	1.3 ± 2.5	4.6	719 (68.9)	1.9 ± 2.8
Muesli or cereal style bars	0.7 ± 1.6	2.4	404 (38.7)	1.8 ± 2.2
Other confectionery	0.7 ± 1.7	2.5	439 (42.1)	1.7 ± 2.4
Infant formula & foods	4.3 ± 5.9	14.9	770 (73.8)	5.9 ± 6.2
Infant & Toddler formula	1.1 ± 3.3	3.8	150 (14.4)	7.7 ± 5.1
Infant foods	2.8 ± 4.4	9.7	658 (63.1)	4.5 ± 4.8
Infant custards or yoghurts	2.8 ± 4.4	9.7	658 (63.1)	4.5 ± 4.8
Infant drinks [d]	0.4 ± 1.7	1.3	155 (14.9)	2.7 ± 3.8
Infant fruit juices	0.4 ± 1.7	1.3	155 (14.9)	2.7 ± 3.8

[a] Food groups providing < 1% contribution to free sugars not listed
[b] Group variation from AUSNUT to match FFQ line items, no difference at major food group level
[c] Free sugars in fruit products & dishes come only from canned fruit in syrup & stewed fruit with added sugar
[d] Infant drinks category includes infant fruit juices, but does not include infant formula or human breast milk

Unflavoured dairy milk substitutes contributed just over 4% of free sugars to the whole cohort, but was one of the highest contributors to free sugars among those 24% of participants who consumed these products. Mean free sugars from this group among consumers was 5.2 g, similar to fruit and vegetable juices and drinks at 5.5 g among consumers (57% of the cohort). These were only secondary to infant and toddler formula, which provided 7.7 g of free sugars to consumers (14% of the cohort). By comparison, dairy milks do not contain any free sugars, nor does breast milk.

Changes in free sugars consumption from 1 to 2 years of age

Table 4.14 compares tertiles of free sugars between 1 and 2 years of age. Nearly half the cohort (45%) remained in the same tertile from 1 to 2 years of age, with 16% of participants categorised in the highest tertile at both time points. Among those who provided both 1 and 2 year data, there was fair agreement between usual free sugars intake relative to the cohort at the two time points (Weighted Kappa 0.241, $p < 0.001$) (Masson et al., 2003).

Table 4.14 Tertile of free sugars intakes from 1 to 2 years of age ($n = 682$)

		Free Sugars at 2 Years		
		Low	**Mid**	**High**
Free Sugars at 1 Year	**Low**	118 (17.3%)	72 (10.6%)	37 (5.4%)
	Mid	82 (12.0%)	76 (11.1%)	70 (10.3%)
	High	49 (7.2%)	67 (9.8%)	111 (16.3%)

Weighted Kappa 0.241, $p < 0.001$

Determinants of high free sugars intakes at 2 years of age

Table 4.15 reports factors associated with high consumption of free sugars at 2 years. In total, 938 participants with complete 2 year dietary data and data for all of the explanatory variables were included in the final multivariable model. Maternal age, country of birth, parity, and level of socio-economic disadvantage were all independently associated with being in the top tertile of free sugars intake and of having free sugars intakes ≥ 10% EER. There was no association observed between both free sugars outcomes and mother's pre-pregnancy BMI or child's sex.

Table 4.15 Participant characteristics associated with high consumption of free sugars at 2 years (*n* = 938).

	Free sugars Highest Tertile		Free Sugars Intake ≥ 10%EER	
	PR	**95%CI**	**PR**	**95%CI**
Mother's age at birth (years)				
<25	1.50	1.07–2.12	1.42	1.05–1.91
25-34.99	1.06	0.84–1.34	1.05	0.85–1.29
≥35	1.00		1.00	
Mother's pre-pregnancy BMI (kg/m^2)				
<25 Healthy weight or below	1.00		1.00	
25-29.99 Overweight	1.06	0.85–1.32	1.03	0.85–1.24
≥30 Obese	0.95	0.74–1.23	0.92	0.73–1.17
Mother's Country of Birth				
Other	1.58	1.28–1.94	1.59	1.33–1.90
Australia, New Zealand	1.00		1.00	
Mother's Education				
University	0.83	0.68–1.01	0.82	0.69–0.98
High school / vocational	1.00		1.00	
IRSAD				
Deciles 1-2 (most disadvantaged)	1.58	1.19–2.10	1.44	1.13–1.84
Deciles 3-4	1.40	1.06–1.85	1.34	1.06–1.70
Deciles 5-6	1.03	0.76–1.40	0.98	0.75–1.29
Deciles 7-8	1.00	0.73–1.38	0.95	0.72–1.25
Deciles 9-10 (most advantaged)	1.00		1.00	
Total number of children				
1	1.00		1.00	
2	1.28	1.04–1.57	1.22	1.02–1.47
≥3	1.52	1.17–1.97	1.39	1.11–1.76
Child's sex				
Female	0.93	0.77–1.11	0.98	0.83–1.15
Male	1.00		1.00	

PR: Prevalence Ratio; CI: Confidence Interval; BMI: Body Mass Index (kg/m^2); IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.

Children of mothers born outside of Australia and New Zealand were more likely to be in the top tertile for both free sugars intake (PR 1.58, 95%CI 1.28–1.94) and free sugars ≥ 10% of EER (PR 1.59, 95%CI 1.33–1.90). Children with two or more siblings were also more likely to be in the top tertile (PR 1.52, 95%CI 1.17–1.97) and to exceed 10% of EER from free sugars (PR 1.39, 95%CI 1.11–1.76) than those with no siblings. Children born to mothers who were less than 25 years old were also more likely to be in the top tertile (PR 1.50, 95%CI 1.07–2.12) and free sugars ≥ 10% of EER (PR 1.42, 95%CI 1.42–1.91). Children from households with the greatest socio-economic disadvantage were more likely to be in the top tertile for free sugars intake (PR 1.58, 95%CI 1.19–2.10) and free sugars ≥ 10% of EER (PR 1.44, 95%CI 1.13–1.84) than the least disadvantaged. Children of mothers with some university education were less likely to have a free sugars intake ≥ 10% of EER (PR 0.82, 95%CI 0.69–0.98), while the association with being in the top tertile of free sugars intake just failed to reach significance (PR 0.83, 95%CI 0.68–1.01).

Sensitivity analysis

Removal of the 125 participants who were assigned a reference EER due to missing weight data resulted in similar overall findings (supplementary Table 4.17 to Table 4.20). In this subset, the median free sugars intake was 22.0 (IQR 12.7–37.6) grams per day, with 70.2% of children exceeding the WHO 5% recommendation, and 37.4% exceeding the 10% recommendation.

4.4.4 Discussion

To our knowledge, this is the first study to investigate free sugars intakes of Australian children from 1 to 2 years of age. Our findings suggest that for many children, recommendations to limit intakes of foods high in added or free sugars during the early years are not being met. Free sugars intakes appear to have increased from 1 to 2 years of age, both in terms of absolute intakes and as a percentage of energy. At 2 years of age, most of the cohort had free sugars intakes that exceeded the WHO < 5% recommendation, and almost two-fifths exceeded the < 10% recommendation. We also found that exceeding the 10% recommendation and being in the highest tertile for free sugars intakes was increasingly observed as socio-economic disadvantage increased.

The 1 and 2 year free sugars data reported here show that the increase in free sugars intake observed from 2 years on in the National Nutrition and Physical Activity Survey (NNPAS), apparently begins early in life. Similar to the findings for older children in the NNPAS (ABS, 2016b), we observed an increase in usual daily intakes of free sugars with age, from median intake of 7.3 g at 1 year of age (Devenish et al., 2019b) to 22.5 g in the same cohort at 2 years of age. These findings are lower than the median free sugars intakes at 2–3 years in the NNPAS, which may be due to the slightly older participants in the national survey, different dietary assessment methods, an increased interest in avoiding sugar in popular media influencing our more recent cohort (Nielsen Scantrack & The George Institute, 2018; Singerman, 2016), social desirability bias in our oral health study affecting sugars reporting, or other factors that remain unknown.

Free sugars intakes as a proportion of energy appear to have increased from 1 to 2 years of age, however these measures differed between the two time points and so these findings should be interpreted cautiously. At 1 year of age, usual energy intake was measured by dietary assessment methods, whereas at 2 years an estimated energy requirement was calculated for each child from their measured weight. Nevertheless, there appears to be a large increase in proportion of energy coming from free sugars, from a mean of 3.6 ± 2.8% of energy intake at 1 year (Devenish et al., 2019b) to 10.4 ± 8.6% of EER at 2 years. Similarly, those exceeding the WHO < 10% recommendation increased from 2.4% of the cohort at 1 year to 38.4% of the cohort at 2 years; and the < 5% recommendation was exceeded by 71.1% at 2 years, up from 22.8% at 1 year (Devenish et al., 2019b). Even with reticence toward the specific values reported here, an overall upward trend is clear.

Similar to our findings at 1 year of age, free sugars intakes at 2 years followed a socio-economic gradient, with increased likelihood of exceeding the WHO recommendation, and of being in the top tertile for free sugars intake among those in lower IRSAD quintiles. This finding is reflected elsewhere among children and adults (ABS, 2015; Cameron et al., 2012; Darmon & Drewnowski, 2008; Spence et al., 2018), and highlights the importance of addressing social determinants across the life course in future efforts to improve dietary behaviours. (Bell et al., 2013; Cameron et al., 2012; Chung et al., 2018; Durao et al., 2017; Spence et al., 2018)

High free sugars intakes were more common among children whose mother was younger and less educated. These findings are consistent with studies that have investigated determinants of diet quality in early childhood, with children of younger mothers and less educated mothers being consistently reported to have poorer quality diets than children of older and more educated women (Bell et al., 2013; Cameron et al., 2012; Chung et al., 2018; Durao et al., 2017; North & Emmett, 2000; Spence et al., 2018). Studies have found that the diets of mothers and young children are correlated (Durao et al., 2017; Lioret et al., 2015), and that education level is associated with diet quality in adults (Backholer et al., 2016c), which likely explains the association between maternal education and child diet quality. Additionally, associations have been found between lower maternal education and the use of food as reward for child behaviour (Musher-Eizenman et al., 2009), which usually includes non-core foods.

The prevalence of being a high free sugars consumer was also greater for children from larger families, and for those whose mother was not born in Australia or New Zealand. It has been suggested that demand from older siblings may increase household exposure to non-core foods, and that caregiving responsibilities of parents may be stretched further in households with multiple children, limiting time for meal preparation (Koh et al., 2010; North & Emmett, 2000). There are many possible contributing factors to why a mother not born in Australia or New Zealand may be a determinant of high free sugars consumption. Two-thirds of SMILE mothers born outside of Australia were born in Asian countries, where there may be cultural norms around sweetening particular foods. For example, providing sweetened tea or milk drinks from a young age is common practice in some Asian and African cuisines (Gulati et al., 2013; Kiwanuka et al., 2006; Yothasamut et al., 2018). Families undergoing nutrition transition tend to retain traditional staple foods, but incorporate the accessory foods of the new country, which are usually non-core foods (Holmboe-Ottesen & Wandel, 2012). Different expectations around the role and autonomy of children in the household may give children a greater degree of influence on household food intake (Wang et al., 2014). Overall, dietary acculturation has generally resulted in a decline in diet quality as families move to a more Western dietary pattern high in non-core foods and associated with affluence (Holmboe-Ottesen & Wandel, 2012; Satia, 2010).

The major sources of free sugars in our cohort at 2 years were mostly non-core foods, and were similar to the major food sources reported in the NNPAS for older children. Fruit and vegetable juices and drinks provided the greatest overall contribution to free sugars intakes in both the NNPAS (25% of free sugars) at 2–3 years and our cohort (11%) at 2 years, and were consumed by 44% of the 2–3 year NNPAS responders and 57% of our cohort. In comparison, approximately 12% of our participants consumed this food group at 1 year of age, giving a lower overall contribution to free sugars (7.4%). So from 1 to 2 years of age, we observed an increase in the number of consumers, mean grams consumed and overall percentage contribution of free sugars coming from fruit and vegetable juices and drinks. Our finding reflects those of Byrne et al. (2018), in another Australian cohort that observed a similar increase in fruit juice-based drinks coupled with a decline in milk-based drinks from 2 to 5 years of age. As the WHO definition of free sugars includes sugars naturally present in fruit juices and concentrates, fruit and vegetable juices and drinks are recognised as a sugar-sweetened beverage, with a contributing role in obesity and dental decay (WHO, 2015). As such, recommendations to limit intakes of fruit juice in children of all ages should be prioritised (NHMRC, 2012a; WHO, 2016).

Infant and toddler foods are a point of difference between our cohort and the NNPAS. These foods appear to have a decreasing role in the diets of toddlers, with fewer consumers and lower overall contribution to free sugars from 1 to 2 years. However, in our cohort this food group still contributed approximately 15% of free sugars at 2 years of age, down from 28% at 1 year, but much greater than the 0.1% reported in the NNPAS. Possible reasons for this discrepancy include more steps taken to differentiate these foods in our data collection methods at both time points, limitations of the infant foods categories in AUSNUT2011–13 and the substantial growth of the infant and toddler food market in recent years (Devenish et al., 2019b; IBISWorld Australia, 2017). Future updates to national nutrient databases will need substantial revisions to the food list and infant food group categories, as the AUSNUT2011–13 database does not reflect the current infant and toddler food market.

Yoghurt was the only core food group contributing substantially to free sugars intakes among all children, with higher proportion in our cohort at 1 year (9.6%) and 2 years (8.8%) than the 6.2% reported in the NNPAS for 2–3 year olds. We also recorded an additional 9.8% of free sugars from the minor food group infant and toddler custards or yoghurts at 2 years, which, although not directly reported in the NNPAS, contributed less than 0.1% of free sugars as part of the sub-major food group infant foods. In addition to the already described reasons for these discrepancies, yoghurts have particularly high variation in sugars content, making this food group difficult to capture accurately in dietary surveys. Products range from plain, unsweetened yoghurt with zero free sugars, to flavoured yoghurts containing over 15 g of free sugars per 100 g. Children's yoghurt pouches seem to exemplify this variation, with products appearing side-by-side on supermarket shelves that contain a three-to-four-fold difference in sugar content for the same flavour across different brands. As a core food, yoghurt is an ideal early food for infants, but products with little or no free sugars should be selected. This finding highlights the importance of transparent food labelling that includes free sugars, consumer education and mandatory front-of-pack nutrition labelling to support consumers and encourage product reformulation (Pulker et al., 2018; Rayner et al., 2013; World Health Organization, 2016).

At present, the Australia New Zealand Food Standards Code does not sufficiently regulate the use of free sugars in infant and toddler food products. Food manufacturers avoid the standard for infant products by labelling foods as suitable for children over 12 months of age. They are also able to sweeten infant foods using fruit juice or fruit juice concentrate, in order to avoid the labelling requirement that infant foods containing more than 4 g per 100 g added sugars must be labelled as "sweetened" (Australian Government, 2017b). Definitions of added sugars often differ from that of free sugars by the exclusion of fruit juice, which has left a loophole in the current food standard. Given the rapid growth in the infant and toddler food market in recent years, the current standards have fallen behind, and action is needed by policymakers to ensure foods marketed to infants and toddlers are low in free sugars, and clearly labelled.

As with compliance with WHO recommendations, direct comparisons of food group contributions should be interpreted cautiously. Slightly different methods were used to assign food group contributions at the two time points, and food groups in the 2 year data were retrospectively assigned to the SMILE-FFQ, which was designed with a focus on sugars at a nutrient rather than food group level. However the AUSNUT2011–13 food groups were used as consistently as possible, with most line items in the SMILE-FFQ matching directly to one major or sub-major food group.

A notable point of difference in the nutrient output between the SMILE-FFQ and the AUSNUT2011–13 database were the attribution of a free sugars value to infant and toddler formula. This was assigned a zero value for free sugars in AUSNUT2011–13, however some of these products, particularly those made from plant-based milk alternatives such as soy, and to a lesser extent toddler formula, contain added sucrose and other sources of free sugars. When designing the nutrient database for the SMILE-FFQ we assigned a conservative free sugars value to the line item for formula, based on cow's milk-based toddler formula, following the method for determining free sugars adapted from Louie et al. (2015). The result was higher than the zero value from most cow's-milk based infant formula, but lower than formula from plant-based alternatives. Similar to other dairy milk alternatives, formula alternatives may be a key source of free sugars among those who consume them. It was not possible to separate out these different formula types due to the single line item in the SMILE-FFQ, and the relatively crude infant food group categories of AUSNUT2011–13. As a result, the contribution to free sugars among consumers of plant-based formula is likely to be underestimated, with a corresponding overestimation for consumers of animal milk-based infant formula.

Given the limited reporting of dietary intakes in the first 2 years of life and the recent release of the WHO (2015) guideline for sugars intake among adults and children, this research provides valuable insight into the early establishment of free sugars intakes of Australian children. We support the recent recommendation by Spence et al. (2018), that national dietary surveys should include children younger than 2 years of age in order to obtain a nationally representative and consistent picture of the establishment of dietary patterns throughout early childhood. However, more work is needed to ensure that infant and toddler foods are accurately captured, via modifications to survey design method and revisions to the food list and infant food groups in the national nutrient database. It is likely that discrepancies between our findings and the most recent NNPAS can be attributed to these methodological and age differences.

Strengths of this study include our cohort recruitment and dietary assessment methods. Initial efforts to over-sample from hospitals in socially disadvantaged areas to address attrition bias have resulted in a study population that is socio-economically diverse and generally representative of the population, based on South Australian perinatal statistics collected in 2013 (Scheil et al., 2015).

The use of a customised FFQ that was designed to capture free sugars in Australian toddlers and validated with an external cohort prior to administration provides robust and valid free sugars intake data at 2 years of age (Devenish et al., 2017). The use of a 24-hour recall and 2-day food diary on non-consecutive days at 1 year of age also resulted in a reliable measure of usual free sugars intake, tailored to the infant and toddler food landscape. Due to the different dietary assessment methods at the two time points, statistical comparisons focused on movement relative to the cohort, rather than absolute values.

A limitation of the study is the relatively small proportion of cases (10%) that were lost from the determinant analysis due to incomplete data for one or more socio-demographic characteristics. However, previous sensitivity analysis for other dietary outcomes investigated in this cohort, in which missing data was imputed under the assumption that data were missing at random, revealed that distributions of variables in the imputed data sets were consistent with the complete case data set (Ha et al., 2017).

All dietary assessment methods have inherent limitations in precision and accuracy, including social desirability bias and other forms of misreporting (NIH & NCI, 2018; Thompson & Subar, 2013; Willett, 2013). In our case, proxy reporting was used due to the age of the cohort, and so the reports may not reflect food intakes of the child when in the care of others. Proxy estimates of quantity intakes of toddlers are likely to be more difficult than of older children due to the small and variable portion sizes experienced at this age, greater frequency of meals and snacks and higher plate waste (Livingstone et al., 2004; Ortiz-Andrellucchi et al., 2010).

The association between sugars intake and dental caries is well-known, and our cohort are aware that SMILE is an oral health study. Participants are likely to have underestimated free sugars intakes due to social desirability bias, particularly at 2 years when they were due to have their oral examination. Some of this underestimation may be ameliorated by the use of EER for determining compliance with the WHO recommendations. In the NNPAS mean daily energy intakes of 2 – 3 year olds exceeded the EER (ABS, 2015), so it is likely that using EER with true free sugars intakes would underestimate actual energy intake and falsely elevate the percentage of energy from free sugars. It is not possible to determine the extent of this bias, or whether it is consistent across the cohort. Underestimation of free sugars or EER may be greater in sub-sets of the cohort, for example those at the extremes of weight values (Radnitz & Todd, 2016), those whose actual energy intake is substantially over or under the EER, or those for whom EER was imputed in the absence of weight data.

4.4.5 Conclusions

This study reports free sugars intakes and food sources among 1 and 2 year old children; an age group not currently included in national dietary monitoring. Findings suggest that free sugars enter the diet somewhat conservatively in the first year of life, and then increase substantially by 2 years of age. National data in older children supports this perceived trend. Noncompliance with the WHO recommendations for free sugars intakes has also increased at 2 years of age, with most of the cohort exceeding the < 5% recommendation, and almost two-fifths exceeding the < 10% recommendation. For the most part, food sources of free sugars reflect those of older children. These are predominantly non-core foods, such as fruit juice, biscuits, cakes, desserts and confectionery; with yoghurt and non-dairy milk alternatives the two notable exceptions. As observed in other settings, we found that diet quality follows a social gradient, with high free sugars consumption more prevalent among 2 year olds from households with greater socio-economic disadvantage.

These findings highlight the need for improved efforts to prevent provision of sources of free sugars in the first years of life. It is important to establish family food and drink intakes that are centred on core foods, and set-up lifelong eating patterns that are associated with reduced risk of obesity, dental caries and other chronic disease. Policymakers and practitioners should consider approaches that support parents in food selection and encourage product reformulation by manufacturers, such as improving the food standard for infant foods to include toddler products and incorporate the WHO definition of free sugars, mandatory front-of-pack nutrition labelling and the addition of free sugars to the nutrition information panel for all products. Parents should be encouraged and supported to limit early exposure to foods high in free sugars, particularly fruit juice and non-core foods. Strategies to address social determinants of health and reduce inequality must be considered, and future interventions should target groups with greater socio-economic disadvantage. Progress in these efforts should be evaluated via ongoing national dietary surveys, to monitor intakes of free sugars and non-core foods throughout the course of life.

Author Contributions: Conceptualisation, GD, DH, LD and JS; Formal analysis, GD, AM and LD; Funding acquisition, DH, LD and JS; Investigation, GD, DH, LD and JS; Methodology, GD, RG, AM, DH and JS; Software, GD and AM; Supervision, RG, AB and JS; Validation, GD; Writing-original draft, GD; Writing-review & editing, GD, RG, AM, AB, DH, LD and JS.

Funding: The SMILE was supported by a NHMRC Project Grant (GNT: 1046219). The authors would like to acknowledge the Australian Government Research Training Program Scholarship in supporting this research.

Acknowledgments: The authors acknowledge Elinor Ytterstad for contributions to the 1 year data analysis, and Yun Zhao for statistical advice for the 2 year data.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

4.4.6 Supplementary Materials

Five supplementary tables are published with this article. Table 4.16 presents participant characteristics of those who completed both the 1 and 2 year dietary questionnaires. The sensitivity analysis is reported in the remaining tables, with Table 4.17 reporting participant characteristics of this sub-set. Table 4.18, Table 4.19, and Table 4.20 reflect the main results tables, re-analysed after removal of the 125 participants who were assigned a reference EER due to missing weight data. Methods were described in 4.4.2, and results discussed in 4.4.3.

Table 4.16 Characteristics of participants who completed both 1 and 2 year dietary questionnaires

	Completed both questionnaires (*n* = 682)			Did not complete both questionnaires (*n* = 1499)			*p* [a]
	n	**mean**	**SD**	***n***	**mean**	**SD**	
Mother's age at birth (years)	680	30.9	4.8	1421	29.4	5.6	<0.001
Total number of children	661	1.7	0.9	1206	1.9	1.0	0.005
Child's birthweight (g)	674	3411	562	1409	3329	575	0.002
Child's age at 24HR (months)	682	13.1	1.0	146	13.1	0.9	0.736
Child's age at FFQ (months)	670	25.2	1.1	451	26.1	2.0	<0.001
	n	**%**		***n***	**%**		
Mother's age at birth (years)							<0.001
<25	55	8.1		281	19.8		
25-34.99	481	70.7		872	61.4		
≥35	144	21.2		268	18.9		
Mother's pre-pregnancy BMI (kg/m^2)							0.002
<25	398	61.8		688	53.4		
25-29.99 (overweight)	132	20.5		323	25.1		
≥30 (obese)	114	17.7		278	21.6		
Mother's Country of Birth							<0.001
Australia or New Zealand	513	75.8		940	66.2		
Other	164	24.2		480	33.8		
Mother's Education							<0.001
high school / vocational	273	40.3		863	60.5		
some university and above	405	59.7		563	39.5		
IRSAD							<0.001
Deciles 1-2 (most disadvantaged)	93	13.7		369	26.3		
Deciles 3-4	141	20.8		305	21.7		
Deciles 5-6	141	20.8		249	17.7		
Deciles 7-8	137	20.2		248	17.7		
Deciles 9-10 (most advantaged)	165	24.4		233	16.6		
Total number of children							0.082
1	320	48.4		543	45.0		
2	240	36.3		430	35.7		
≥3	101	15.3		233	19.3		
Child's sex							0.175
Male	374	54.8		772	51.7		
Female	308	45.2		721	48.3		
Mother's smoking status at 1 year							0.035
no	625	93.0		540	89.7		
yes	47	7.0		62	10.3		

[a] *p* values for responders vs non-responders at using t-test (continuous) or Pearson Chi Square test (categorical). SD: Standard Deviation; 24HR: 24-hour recall; FFQ: Food Frequency Questionnaire; BMI: Body Mass Index. IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.

Table 4.17 Participant characteristics, sub-set for sensitivity analysis: responders at 2 years with calculated EER from weight data vs reference EER imputed for age and sex.

	Calculated EER from weight (n = 918)			Imputed (reference) EER (n = 125)			p [a]
	n	**mean**	**SD**	***n***	**mean**	**SD**	
Mother's age at birth (years)	915	30.6	4.9	125	30.2	5.4	0.483
Total number of children	890	1.8	0.9	123	1.7	0.9	0.806
Child's birthweight (g)	908	3398	548	124	3355	537	0.411
Child's age at FFQ (months)	895	25.5	1.5	120	25.6	1.6	0.433
	n	**%**		***n***	**%**		***p*** [a]
Mother's age at birth (years)							0.043
<25	86	9.4		19	15.2		
25-34.99	642	70.2		75	60.0		
≥35	187	20.4		31	24.8		
Mother's pre-pregnancy BMI (kg/m^2)							0.351
<25	493	57.1		72	64.3		
25-29.99 (overweight)	197	22.8		21	18.8		
≥30 (obese)	173	20.0		19	17.0		
Mother's Country of Birth							0.799
Australia or New Zealand	665	73.1		90	72.0		
Other	245	26.9		35	28.0		
Mother's Education							0.903
high school / vocational	396	43.4		55	44.0		
some university and above	516	56.6		70	56.0		
IRSAD							0.256
Deciles 1-2 (most disadvantaged)	144	15.8		28	22.6		
Deciles 3-4	195	21.4		19	15.3		
Deciles 5-6	183	20.1		27	21.8		
Deciles 7-8	177	19.4		22	17.7		
Deciles 9-10 (most advantaged)	213	23.4		28	22.6		
Total number of children							0.734
1	421	47.3		59	48.0		
2	322	36.2		47	38.2		
≥3	147	16.5		17	13.8		
Child's sex							0.755
Male	491	53.5		65	52.0		
Female	427	46.5		60	48.0		
Mother's smoking status at 1 year							0.135
no	767	92.9		95	88.8		
yes	59	7.1		12	11.2		

[a] *p* values for calculated versus imputed EER using t-test (continuous) or Pearson Chi Square test (categorical).
EER: Estimated Energy Requirement; SD: Standard Deviation; FFQ: Food Frequency Questionnaire;
BMI: Body Mass Index. IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.

Table 4.18 Free sugars intakes at 2 years of age, sub-set for sensitivity analysis: responders with imputed EER excluded (n = 918).

		Percentile		
	Median	**25th**	**75th**	**Range**
Free Sugars (g/day)	22.0	12.7	37.6	0.6–140.7
Total Sugars (g/day)	77.2	55.6	104.7	9.4–294.8
Estimated Energy Requirement (kJ/day)	4841	4394	5260	2644–8193
Percentage of Estimated Energy Requirement from Free Sugars (%)	7.5	4.5	13.2	0.2–61.3

EER: Estimated Energy Requirement

Table 4.19 Tertile of free sugars intakes from 1 to 2 years of age, sub-set for sensitivity analysis: responders with imputed EER excluded (n = 623)

		Free Sugars at 2 Years		
		Low	**Mid**	**High**
Free Sugars at 1 Year	**Low**	104 (16.7%)	66 (10.6%)	34 (5.5%)
	Mid	76 (12.2%)	68 (10.9%)	68 (10.9%)
	High	48 (7.7%)	60 (9.6%)	99 (15.9%)

Weighted Kappa 0.241, $p < 0.001$

Table 4.20 Characteristics associated with high consumption of free sugars at 2 years, sub-set for sensitivity analysis: responders with imputed EER excluded (*n* = 829)

	Free sugars Intake Highest Tertile		Free Sugars Intake ≥ 10%EER	
	PR	**95%CI**	**PR**	**95%CI**
Mother's age at birth (years)				
<25	1.59	1.10–2.30	1.51	1.09–2.11
25-34.99	1.11	0.84–1.44	1.09	0.86–1.38
≥35	1.00		1.00	
Mother's pre-pregnancy BMI (kg/m^2)				
<25 Healthy weight or below	1.00		1.00	
25-29.99 Overweight	1.08	0.86–1.38	1.02	0.82–1.26
≥30 Obese	0.98	0.75–1.28	0.92	0.71–1.19
Mother's Country of Birth				
Other	1.47	1.18–1.84	1.54	1.26–1.88
Australia, New Zealand	1.00		1.00	
Mother's Education				
University	0.84	0.68–1.04	0.83	0.68–1.01
High school / vocational	1.00		1.00	
IRSAD				
Deciles 1-2 (most disadvantaged)	1.49	1.10–2.02	1.40	1.06–1.84
Deciles 3-4	1.32	0.99–1.78	1.34	1.04–1.73
Deciles 5-6	0.95	0.68–1.33	0.93	0.69–1.26
Deciles 7-8	0.99	0.71–1.37	0.98	0.73–1.31
Deciles 9-10 (most advantaged)	1.00		1.00	
Total number of children				
1	1.00		1.00	
2	1.31	1.05–1.64	1.20	0.98–1.47
≥3	1.42	1.07–1.88	1.33	1.03–1.72
Child's sex				
Female	0.90	0.74–1.10	0.94	0.79–1.12
Male	1.00		1.00	

PR: Prevalence Ratio; 95%CI: 95% Confidence Interval; BMI: Body Mass Index (kg/m^2); IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.

4.5 Summary

This chapter describes intakes of free sugars by the SMILE cohort at 1 and 2 years of age, filling a gap in Australian dietary intake data. Findings suggest that free sugars enter the diet somewhat conservatively in the first 6 months of weaning, and then increase substantially by the second year of life. National data in older children supports this perceived trend. At 2 years of age, most children are exceeding the WHO recommendation that free sugars provide less than 5% of energy, and almost two-fifths are exceeding the less than 10% recommendation.

Food sources of free sugars are predominantly non-core foods, and largely reflect the major food sources of free sugars for older children. The predominant core foods that emerged as sources of free sugars were yoghurt and non-dairy milk alternatives, both of which experience high variation in free sugars content across different brands of similar products. Infant and toddler foods were identified as a key source of free sugars in early childhood, highlighting the need for improved food standards, and revisions to national monitoring methods.

As observed in other settings, diet quality follows a social gradient, with high free sugars consumption more prevalent among pre-schoolers from households with greater socio-economic disadvantage. These households also experience lower access to dental services, which may have a compounding effect on caries experience.

The next chapter explores the overall thesis question around infant feeding practices and early childhood caries, using the free sugars values reported here as explanatory variables in the analysis.

Chapter 5 Early Childhood Feeding and Dental Caries

5.1 Overview

This chapter presents the culmination of the work of this thesis, using the SMILE data to investigate associations between breastfeeding practices and early childhood caries, while controlling for a range of dietary and socio-demographic risk factors.

The chapter is presented by the following paper:

> Devenish, G.; Mukhtar, A.; Begley, A.; Thomson, W.M.; Spencer, A.J.; Ha, D.; Do, L.; Scott, J. (2020). Early childhood feeding practices and dental caries among Australian pre-schoolers. *The American Journal of Clinical Nutrition*. doi:10.1093/ajcn/nqaa012

This paper addresses the primary aim of this work, via objective 5, which is to a*ssess the relationship between infant feeding practices and ECC, controlling for key dietary and demographic factors, in a cohort of Australian children experiencing universal fluoride coverage* (Table 1.1, p. 3).

5.2 Original Research: Early Childhood Feeding Practices and Dental Caries Among Australian Pre-Schoolers

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Abstract: *Background* Recent reviews propose a causal relationship between prolonged breastfeeding and early childhood caries (ECC), but the evidence to date is inconsistent, with few cohort studies and limited investigation of key confounders.
Objective This study aimed to investigate the relationship between dietary practices and early childhood caries in a birth cohort of Australian toddlers.
Design Participants underwent a standardised dental examination at 2–3 years of age to determine the prevalence of ECC (based on the presence of decayed, missing or filled tooth surfaces). Breastfeeding practices were reported at 3, 6, 12 and 24 months of age. Free sugars intakes were assessed at 1 year and 2 years of age. Multivariable regression models generated prevalence ratios (PR) for the association between ECC and breastfeeding duration, and between ECC and sleep feeding practices at 1 year, controlling for socio-demographic factors and free sugars intake.
Results There was no independent association between breastfeeding beyond 1 year of age and ECC (PR 1.42, 95% CI 0.85, 2.38), or between breastfeeding to sleep and ECC (PR 1.12, 95% CI 0.67, 1.88), although the direction of effect was suggestive of an association. The only factors independently associated with ECC were high free sugars intakes (PR 1.97, 95% CI 1.13, 3.44), and greater socio-economic disadvantage (PR 2.15, 95% CI 1.08, 4.28). Most participants who were breastfed at 1 year of age had ceased by 18 months or 2 years. *Conclusions* Breastfeeding practices were not associated with ECC. Given the wide-ranging benefits of breastfeeding, and the low prevalence of sustained breastfeeding in this study and Australia in general, recommendations to limit breastfeeding are unwarranted, and breastfeeding should be promoted in line with global and national recommendations. To reduce the prevalence of early childhood caries, improved efforts are needed to limit foods high in free sugars.

Keywords: infant feeding; breastfeeding; early childhood caries; free sugars; food frequency questionnaire; 24-hour recall; food record; fluoride; cohort study.

5.2.1 Introduction

The benefits of breastfeeding for the infant and mother are unparalleled and continue well into the second year of life (Victora et al., 2016). Despite this, breastfeeding initiation and duration rates fail to meet guidelines set by national and global institutions (NHMRC, 2012a; WHO, 2003b). In Australia, only 60% of infants are consuming some breast milk at 6 months of age, and only 18% of toddlers aged 13 to 18 months are still consuming breast milk (AIHW, 2011).

Recent reviews have recognised a relationship between breastfeeding practices and early childhood caries (ECC) (Cui et al., 2017; Moynihan et al., 2019; Tham et al., 2015). Findings suggest there is a protective effect of breastfeeding in the first 6-12 months of life relative to no breastfeeding, but that there is also greater ECC prevalence when breastfeeding is continued beyond the first year of life. The age at which breastfeeding begins to have a detrimental effect on oral health is not known, with studies using a variety of cut-points including 12 months (Feldens et al., 2010b), 18 months (Tanaka et al., 2013), and 24 months and beyond (Peres et al., 2017). In addition, an association between night-time breastfeeding and higher risk of ECC has been proposed (Nakayama & Mori, 2015; Tham et al., 2015). Few studies have investigated this relationship, and many of those score poorly for their study design (Tham et al., 2015). Overall, the evidence to date has been inconsistent and the reviews call for more, higher quality research which controls for relevant confounding factors and covariates, including the consumption of sweet foods and drinks (Cui et al., 2017; Moynihan et al., 2019; Tham et al., 2015).

Early childhood caries is defined as “the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child under the age of six” (Phantumvanit et al., 2018). It occurs as the result of the interaction between fermentable carbohydrate, predominantly free sugars, and cariogenic microorganisms on a susceptible tooth and host over a period of time (Colak et al., 2013; Moynihan & Kelly, 2014). This interaction is moderated by a range of proximal and distal determinants, including fluoride exposure, oral health practices, other dietary factors and feeding behaviours, maternal and family characteristics, socio-economic status, access to and availability of dental and public health services, and other structural, political and cultural influences (Colak et al., 2013; Fisher-Owens et al., 2007).

The consequences of untreated ECC are both short- and long-term. In Australia, children aged 5-9 years have the highest rate of potentially preventable hospitalisations related to dental conditions of any age group (AIHW, 2019). Quality of life and the general health of infants and children with ECC can quickly diminish as the disease progresses and the associated pain and discomfort increase (Colak et al., 2013). ECC is a key determinant of adult dental caries experience, with lasting health impacts throughout life (AIHW, 2019). More action is needed to reduce the burden of disease attributed to ECC, including research to clarify key determinants, including breastfeeding (Phantumvanit et al., 2018; Tham et al., 2015). Reducing the harms from ECC is important, as is minimising the harms from not breastfeeding beyond 1 year of age.

The aim of this study was to investigate the relationship between early childhood feeding practices and ECC in a cohort of Australian pre-schoolers.

5.2.2 Participants and Methods

The Study of Mothers' and Infants' Life Events affecting oral health (SMILE) is a birth cohort study of 2147 mothers and 2181 children, including 34 sets of twins. Participants were recruited from the major maternity hospitals in Adelaide, South Australia, between July 2013 and August 2014 and will be followed until at least 2022. Study methods, including sampling, study size, recruitment and data collection, are described in detail elsewhere (Do et al., 2014). Women from hospitals in lower socio-economic areas were oversampled to account for higher attrition rates, and all new mothers with sufficient English competence and not intending to move out of the greater Adelaide area within a year were invited to participate. All mothers gave written, informed consent. The study was approved by the Southern Adelaide Clinical Human Research Ethics Committee (HREC/50.13, approval date: 28 Feb 2013) and the South Australian Women and Children Health Network (HREC/13/WCHN/69, approval date: 7 August 2013).

A paper-based questionnaire was completed at recruitment, and subsequent questionnaires were administered via the participant's choice of paper, online, or telephone interview when the child was 3 months, 6 months, 1 year and 2 years of age. A 24-hour recall and 2-day food record were completed at 1 year, a food frequency questionnaire at 2 years, and a dental examination was conducted between 2–3 years of age (median 29 months, interquartile range 27-32 months).

Early Childhood Caries

A small team of dental practitioners conducted oral epidemiological examinations after the child's second birthday. Standard clinical indices, developed at the Australian Research Centre for Population Oral Health (ARCPOH) based on the US National Institute of Dental and Craniofacial Research (2002) protocol and the International Caries Detection and Assessment System (Ismail et al., 2007), were used. The ARCPOH protocol was used in the most recent Australian National Child Oral Health Study (Do & Spencer, 2016), and assesses tooth presence, non-cavitated and cavitated carious lesions, filling tooth surfaces, non-carious developmental defects and gingival conditions. The practitioners underwent training and calibration procedures prior to commencement to ensure standardised examination methods were followed. Examinations were conducted under an external headlamp and an intra-oral fibre optic light (MirrorLite). Teeth were cleaned with cotton rolls and dried with compressed air. Five surfaces per tooth of all present teeth were assessed allowing for estimating prevalence of caries at non-cavitated and cavitated levels as well as decayed, missing or filled tooth surfaces (dmfs). The presence of early childhood caries (Yes/No), was used as the outcome variable; detected at a dmfs score ≥ 1, including any non-cavitated lesions, in keeping with the definition of ECC (Phantumvanit et al., 2018). The date of the dental examination was recorded and used to calculate the age in months of the child at the time of the examination.

Breastfeeding

In each questionnaire, participants were asked whether their child was currently receiving any breast milk. If they reported 'no' they were asked at what age their child stopped receiving breast milk (in weeks and/or months). The first reported age of cessation was used, with those reporting in weeks divided by 4.33, to determine breastfeeding duration in months.

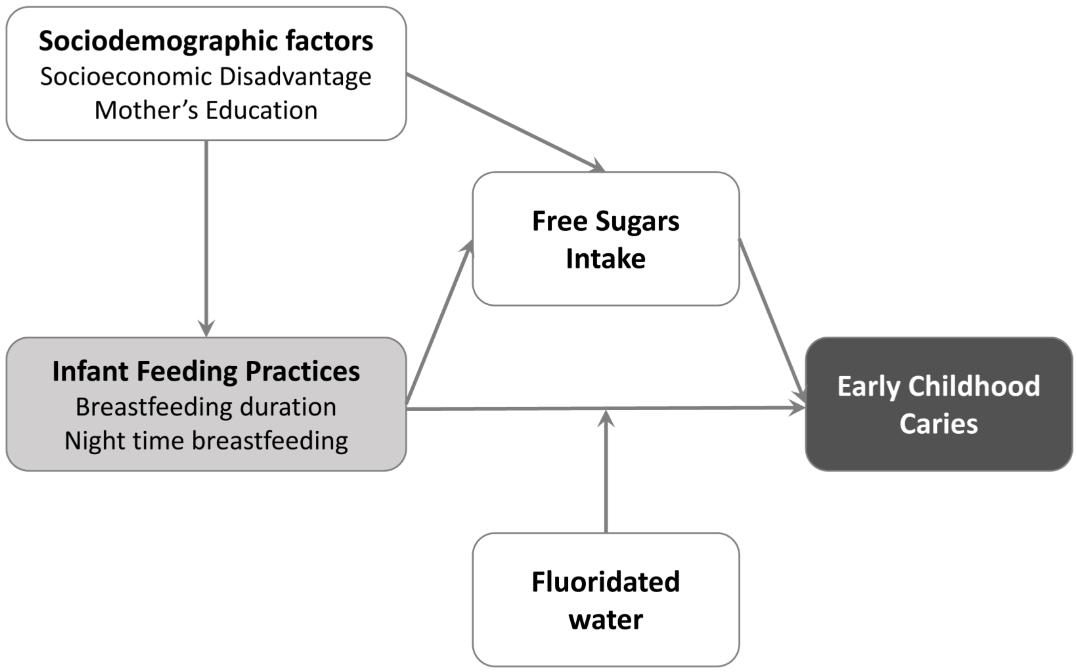
Studies to date have been inconsistent in their definition of prolonged breastfeeding, so initial univariate analyses were conducted exploring 12-month, 18-month and 24-month cut-offs. That we did not find an association at any of these ages may be due to the relatively low prevalence of ECC in the cohort, or the small sample with prolonged breastfeeding beyond 18 months (14% of those who completed the dental examination) or 24 months (9%), so the age categories after 1 year were combined for multivariate analysis. Most children in Australia are still receiving some breast milk at 6 months of age (AIHW, 2011), and so breastfeeding for 6 to < 12 months was selected as the reference category, in order to explore whether ECC was associated with deviating from this norm in either direction. During initial statistical investigations, the association with breastfeeding duration was explored using minimal breastfeeding (0 to < 1 month) as the reference category, as well as with breastfeeding as a continuous variable, but the overall findings did not differ. Breastfeeding duration in the final model was therefore categorised as minimal (0 to < 1 month), breastfed for 1 to < 6 months, breastfed for 6 to < 12 months (reference category), and sustained (≥ 12 months).

When the child was 1 year old, parents were asked whether they breastfed their child during the night, whether they put their child to bed with a bottle, and if so, what was usually in the bottle. If they reported putting their child to bed with only expressed breast milk in the bottle, responses were grouped with those who breastfed to sleep. If they reported only putting their child to bed with water in the bottle, responses were grouped with those who did not put their child to bed with a bottle. The remaining bottle contents included infant formula, cow's milk, other milks, fruit juice/juice drinks and other (please specify), and were grouped into a single variable. Responses were then combined to create the following categories for sleep feeding practices at 1 year: 'no feeding to sleep' (reference category), 'breast but not bottle feeding to sleep', 'bottle but not breast feeding to sleep' and 'mixed feeding to sleep'. The mixed feeding category included those who reported both night-time breastfeeding and bottle feeding with liquids other than water.

Covariates

To guide our analyses, a directed acyclic graph of causal pathways between infant feeding and ECC (Figure 5.1) was first developed, identifying the mother's education and area-level socio-economic status as key confounders, with the child's intake of free sugars as a mediator, and fluoride as a potential effect modifier (Ha et al., 2019; Moynihan et al., 2019; Tham et al., 2015).

Figure 5.1 Directed acyclic graph of the pathways between infant feeding practices and early childhood caries



At recruitment, mothers were asked to report the highest level of education they had attained, and this was later grouped into 'high school/vocational', and 'some university and above'. The area-level Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) was derived from postcode reported at recruitment (Australian Bureau of Statistics, 2013) and then grouped into decile pairs, with a score of 1–2 being 'most disadvantaged' and 9–10 'most advantaged'. Both were included in the model as they measure different aspects of socio-economic position; one at the area level and the other at the individual level.

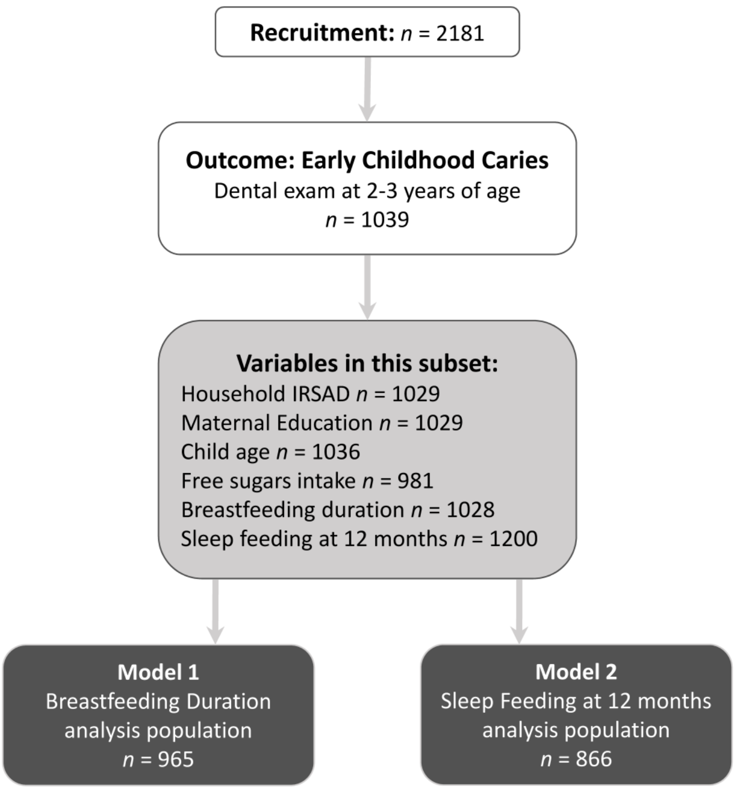
Free sugars intakes were assessed via 24-hour recall and 2-day estimated food record at 1 year of age, and a specially designed and externally validated food frequency questionnaire (Devenish et al., 2017) at 2 years. Dietary collection methods, along with findings for free sugars intakes, food groups and determinants are reported in detail elsewhere (Devenish et al., 2019a; Devenish et al., 2019b). Free sugars intakes were reported in terms of compliance with the WHO (2015) guideline for sugars intake for adults and children. This guideline recommends limiting intakes of free sugars to less than 10% of energy intake, and conditionally recommends a further reduction to less than 5% of energy. Data at 1 and 2 years of age were combined into a single variable based on overall compliance with the WHO guideline, categorised as 'noncompliant' (> 10% of energy on both occasions), 'partially noncompliant' (> 10% energy on one but not both occasions), 'semi-compliant' (< 10% on both occasions, but > 5% on at least one occasion), and 'compliant' (< 5% of energy on both occasions). The WHO definition of free sugars was used, which states that "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" (2015, p. 4).

The greater Adelaide area has comprehensive water fluoridation within the recommended range of 0.6 - 1.1 mg/L (NHMRC, 2017b), and so fluoride was not included in the multivariable models. In order to investigate whether some participants were not being exposed to fluoride, participants were asked about the predominant sources of the water consumed by their child in all questionnaires. A low-fluoride exposure variable was generated, defined as those who reported main sources other than tap/public water in at least two out of three questions in the 1 and 2 year questionnaires. Fewer than 15% of the cohort were identified as having low mains water fluoride exposure (n = 157) based on self-reporting of main water sources and use of water filters. Among these, ECC was present in only 6 participants (4% of low-fluoride exposed), so no further investigations were conducted in this sub-set.

Statistical Analysis

Multivariable log-binomial regression models using Poisson distribution were generated with the PROC GENMOD procedure using SAS v9.4 (SAS Institute Inc., Cary, NC, USA). Early childhood caries prevalence ratios (PR) and their 95% confidence intervals (CI) were determined for both breastfeeding duration and sleep feeding practices at 1 year after adjusting for the confounding variables maternal education, IRSAD score, child age at time of dental examination, and free sugars intake. Variance inflation factors were employed to check multi-collinearity between factors. All values were well below 3, so it was possible to keep all the factors in the model (Hair Jr. et al., 2014). As free sugars intake is a mediator rather than confounder, models were also run excluding sugars, for comparison to the final model (see 5.2.6 Supplementary Materials). Prevalence ratios were selected over odds ratios as they were considered simple to interpret and appropriate for this outcome and prevalence rate (Tamhane et al., 2016). There were minimal missing data for confounding variables (Figure 5.2). A previous sensitivity analysis for other outcomes investigated in this cohort, in which missing data for socio-demographic explanatory variables were imputed under the assumption that data were missing at random, revealed that distributions of variables in the imputed data sets were consistent with the complete case data (Ha et al., 2017). On this basis, participants with data missing for one or more of the explanatory variables were excluded from this analysis (model 1 *n* = 74, 7% of those who completed the dental examination; model 2 *n* = 173, 17%).

Figure 5.2 Participant flowchart for the analysis datasets



IRSAD, Index of Relative Socio-economic Advantage and Disadvantage

5.2.3 Results

Participants

Figure 5.2 depicts participant flow. There were 965 participants with complete data for all variables that made up the analysis cohort for breastfeeding duration, and 866 for sleep feeding at 1 year. Table 5.1 reports participant characteristics of those in the two analysis cohorts. Supplementary Table 5.3 compares characteristics of those who completed the dental examination with the full recruitment cohort. Those who completed the dental examination were more likely to come from households with higher IRSAD score (more advantaged), be born to older and more educated mothers, breastfed to a later age and with lower free sugars intakes than those who did not complete the examination.

Of the 1039 children who completed the dental examination, early childhood caries was present in 110 (10.6%). Mean breastfeeding duration was 10 months, with 40% of children who completed the dental examination still receiving some breast milk at 1 year of age. Most participants in our cohort who were still breastfed at 1 year of age (40%) had ceased by 18 months (14% still breastfeeding) or 2 years (9% still breastfeeding). For this reason, we selected the term 'sustained' rather than 'prolonged' to describe this group. Most of the cohort had moderate free sugars intakes, with 29% compliant with the WHO < 5% recommendation at both time points, but 14% exceeding the < 10% recommendation at both.

Early Childhood Feeding Practices and Dental Caries

There was no association between breastfeeding beyond 1 year of age and ECC in this cohort (PR 1.42, 95% CI 0.85, 2.38), relative to breastfeeding between 6 and 12 months of age, although the size and direction of the effect was suggestive of an association (Table 5.2). The only variables that were significantly associated with ECC in the first model were free sugars intakes and socio-economic disadvantage (IRSAD). There was a greater likelihood of ECC among children whose free sugars intake exceeded the WHO < 10% energy recommendation at 1 and 2 years of age (PR 1.97, 95% CI 1.13, 3.44) than those with intakes below the WHO < 5% of energy recommendation at both time points. Additionally, children from households with the greatest socio-economic disadvantage were more likely to have ECC than those from households with the most advantage (PR 2.15, 95% CI 1.08, 4.28). There was no association between breastfeeding to sleep (PR 1.12, 95% CI 0.67, 1.88) or bottle feeding to sleep (PR 0.66, 95% CI 0.37, 1.16) at 1 year and ECC in the second model, relative to no sleep feeding, with only IRSAD showing an association with ECC. The removal of free sugars did not change the overall findings for either model (Supplementary Table 5.4).

Table 5.1 Participant characteristics, analysis datasets

	Breastfeeding duration analysis dataset (*n* = 965)			**Sleep Feeding analysis dataset (*n* = 866)**		
	n	**mean**	**SD**	***n***	**mean**	**SD**
Mother's age at birth (years)	965	30.5	4.9	866	30.6	4.9
Breastfeeding duration (weeks)	965	43.3	32.8	865	43.9	32.8
Child's age at dental exam (months)	965	29.7	3.4	866	29.6	3.4
Child's birthweight (g)	957	3391	555	859	3398	549
	n	**%**		***n***	**%**	
Early Childhood Caries [1]						
Yes	98	10.2		84	9.7	
No	867	89.8		782	90.3	
Breastfeeding duration						
0 - <1 months (minimal)	94	9.7		82	9.5	
1 - <6 months	257	26.6		227	26.2	
6 - <12 months	228	23.6		201	23.2	
≥12 months (sustained)	386	40.0		355	41.0	
Feeding to sleep aged 1 year						
Mixed feeding	20	2.3		20	2.3	
Bottle but not breast feeding	244	28.2		245	28.3	
Breast but not bottle feeding	211	24.4		211	24.4	
No feeding to sleep	390	45.1		390	45.0	
Free Sugars intakes [2]						
Noncompliant	134	13.9		91	10.5	
Partially noncompliant	224	23.2		219	25.3	
Semi compliant	326	33.8		297	34.3	
Compliant	281	29.1		259	29.9	
Mother's Education						
High school / vocational	424	43.9		366	42.3	
Some university & above	541	56.1		500	57.7	
IRSAD [3]						
Deciles 1–2	151	15.6		122	14.1	
Deciles 3–4	206	21.3		189	21.8	
Deciles 5–6	198	20.5		182	21.0	
Deciles 7–8	187	19.4		167	19.3	
Deciles 9–10	223	23.1		206	23.8	
Fluoride avoider						
Yes	123	13.3		111	13.3	
No	802	86.7		726	86.7	

[1] Presence of Early Childhood Caries, based on the presence of decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth (Phantumvanit et al., 2018).
[2] Free sugars intakes compliance with the WHO (2015) guideline categorised as noncompliant (free sugars > 10% of energy on both occasions), partially noncompliant (> 10% on one but not both occasions), semi-compliant (< 10% on both occasions, but >5% on at least one occasion), and compliant (< 5% on both occasions).
[3] IRSAD: Index of Relative Socio-economic Advantage and Disadvantage, where decile 1 is most disadvantaged and 10 is most advantaged (ABS, 2013).

Table 5.2 Early childhood feeding practices and dental caries at 2 3 years of age[1]

	ECC Prevalence [1]					
	Unadjusted		Model 1: Breastfeeding duration (n = 965)		Model 2: Feeding to sleep (n = 866)	
	PR [2]	*95% CI*	*PR*	*95% CI*	*PR*	*95% CI*
Breastfeeding duration						
0 - <1 months (minimal)	0.69	0.30, 1.61	0.64	0.25, 1.62		
1 - <6 months	0.82	0.46, 1.46	0.85	0.46, 1.56		
6 - <12 months	1.00		1.00			
≥ 12months (sustained)	1.30	0.80, 2.11	1.42	0.85, 2.38		
Feeding to sleep aged 1 year						
Mixed feeding	1.90	0.68, 5.34			1.89	0.66, 5.40
Bottle but not breast feeding	0.80	0.47, 1.37			0.66	0.37, 1.16
Breast but not bottle feeding	1.24	0.76, 2.05			1.12	0.67, 1.88
No feeding to sleep	1.00				1.00	
Free Sugars intakes [3]						
Noncompliant	1.97	1.14, 3.39	1.97	1.13, 3.44	1.78	0.93, 3.43
Partially noncompliant	0.90	0.50, 1.61	0.85	0.47, 1.53	0.75	0.40, 1.39
Semi compliant	0.92	0.55, 1.56	0.89	0.52, 1.52	0.89	0.51, 1.54
Compliant	1.00		1.00		1.00	
Mother's Education						
High school / vocational	0.90	0.61, 1.32	0.78	0.51, 1.21	0.72	0.45, 1.14
Some university & above	1.00		1.00		1.00	
IRSAD [4]						
Deciles 1–2	1.77	0.94, 3.36	2.15	1.08, 4.28	2.38	1.10, 5.16
Deciles 3–4	1.77	0.97, 3.24	2.06	1.08, 3.93	2.49	1.23, 5.04
Deciles 5–6	1.27	0.66, 2.44	1.38	0.69, 2.78	1.54	0.72, 3.30
Deciles 7–8	1.55	0.82, 2.92	1.67	0.85, 3.27	1.99	0.95, 4.16
Deciles 9–10	1.00		1.00		1.00	

[1] Presence of Early Childhood Caries, based on the presence of decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth (Phantumvanit et al., 2018).
[2] PR: Prevalence Ratio, 95% CI: Confidence Interval; derived using multivariable regression
[3] Free sugars intakes compliance with the WHO (2015) guideline categorised as noncompliant (free sugars > 10% of energy on both occasions), partially noncompliant (> 10% on one but not both occasions), semi-compliant (< 10% on both occasions, but >5% on at least one occasion), and compliant (< 5% on both occasions).
[4] IRSAD: Index of Relative Socio-economic Advantage and Disadvantage, where decile 1 is most disadvantaged and 10 is most advantaged (ABS, 2013).

5.2.4 Discussion

In this cohort of toddlers, neither the duration of breastfeeding, nor night-time breastfeeding practices at 1 year were associated with early childhood caries. However, the direction and size of the effect of the relationship between sustained breastfeeding and risk of ECC suggested a higher risk. To date, few epidemiological studies have provided data on the prevalence of ECC in toddlers (Cui et al., 2017), and the low incidence of ECC and prevalence of breastfeeding beyond 12 months in this population in combination may have contributed to a rare events bias. The SMILE continues to follow this cohort into primary school, and further dental examinations will be conducted at 5 and 7 years of age. A higher prevalence of ECC is expected at these ages due to the progressive nature of the disease, which will allow confirmation or clarification of these findings.

Nevertheless, our findings are similar to those of two cohort studies in Brazil (Feldens et al., 2010b; Peres et al., 2017) and one in Japan (Tanaka et al., 2013) which found no association with ECC risk among children breastfed beyond 12 or 18 months relative to those breastfed for less than 6 or 12 months of age. A recent systematic review found that although study quality to date has been inconsistent, breastfeeding up to 2 years did not appear to increase ECC risk relative to breastfeeding up to 1 year (Moynihan et al., 2019). The review did note that durations beyond 2 years may be associated with higher ECC prevalence, informed by two cohort studies from Brazil (Chaffee et al., 2014; Peres et al., 2017), along with one case control and five cross-sectional studies.

These studies and the results of our study support the continuation of breastfeeding into the second year of life; however, further studies in populations with longer durations of follow-up are needed to investigate ECC risk with continued breastfeeding beyond 2 years of age. Given the low breastfeeding rates beyond 2 years in Australia and other high-income countries (Victora et al., 2016), messages to limit breastfeeding in these populations are unwarranted.

There are notable inconsistencies in the evidence for an association between sustained breastfeeding and higher risk of ECC (Moynihan et al., 2019; Tham et al., 2015), which may be explained in part by the level of exposure of different cohorts to a fluoridated water supply, which is seldom adjusted for in studies of this kind. Recent data from the Australian National Oral Health Study observed greater caries experience among children breastfed beyond 2 years of age that was present only in participants without exposure to fluoridated water (Ha et al., 2019). This modifying effect of fluoride on caries progression could be a contributing factor to the failure of this study to find an association between sustained breastfeeding and higher rates of ECC, as all participants lived in the greater Adelaide area with access to a fluoridated mains water supply.

This study addressed one of the limitations of other studies by adjusting for the intake of sweet foods and beverages, and found the only modifiable behaviour associated with greater prevalence of ECC was having an intake of free sugars exceeding 10% of energy intake. Although free sugars intakes were not the main variable of interest in this analysis, our findings support the extensive body of literature demonstrating an association between high free sugars intakes and greater ECC prevalence (Moynihan & Kelly, 2014). Sugar has been recognised as the most important dietary factor in the development of dental caries (Moynihan & Kelly, 2014; Sheiham & James, 2015), and although the evidence for this association is well established, there is continued need to investigate the lower level of no effect among populations (Moynihan & Kelly, 2014; Sheiham & James, 2014).

Free sugars intakes are not necessary for a healthy diet and are associated with obesity as well as tooth decay (WHO, 2015), Proposed strategies to reduce intakes of free sugars have highlighted a range of policy actions, including a sugar-sweetened beverages tax (Backholer et al., 2016a; Lal et al., 2017), improved front of pack labelling (Jones et al., 2018; Moore et al.; PHAA, 2017b), the mandatory addition of added or free sugars to nutrition information panels (PHAA, 2018d) and regulation of the use of free sugars in infant and toddler foods (Devenish et al., 2019b).

Our finding that ECC prevalence follows a socio-economic gradient is consistent with the literature which shows this association throughout the life-course (Armfield & Spencer, 2008). Among adults and older children, this is partially explained by disparities in access to dental services due to cost (AIHW, 2019). We have also observed an association between socio-economic disadvantage and high free sugars intakes in this population (Devenish et al., 2019a), and it is likely that there are other contributing factors not captured here. The impacts of intergenerational disadvantage begin to appear in early childhood, and this is an emerging area of research (McEwen & McEwen, 2017).

A strength of our study is the comprehensive measurement of free sugars intakes, with most other studies not controlling for free sugars intakes at all, or using non-validated dietary assessment methods or proxy indicators (Moynihan et al., 2019; Phantumvanit et al., 2018). The SMILE food frequency questionnaire was designed to address this, as the tool estimates usual intake of total and free sugars, and was validated in an external cohort of Australian toddlers (Devenish et al., 2017). Recent systematic reviews have been unable to pool datasets due to the diversity in sugars measurement and reporting (Moynihan et al., 2019; Moynihan & Kelly, 2014), so our use of the WHO definition of free sugars in the design of the SMILE food frequency questionnaire and our reporting against the WHO criteria may make future pooled meta-analysis possible.

Despite our efforts to minimise reporting bias, all dietary assessment methods have inherent limitations with regard to precision and accuracy (NIH & NCI, 2018). In particular, our use of proxy reporting from the parents may be subject to social desirability bias and not fully reflect the food landscape experienced by the child, particularly when in the care of others.

The low prevalence of both the primary exposure variable and the outcome variable may have introduced a rare events bias, thereby limiting the conclusions that can be drawn from our findings. A further limitation is that fewer than half of the recruited cohort completed the dental examination. This resulted in a sample size that was lower than the target of 1,398, calculated for 90% statistical power (Do et al., 2014); however, a post-hoc calculation for this analysis estimated statistical power of 82%. As anticipated, there was greater socio-economic advantage in the final analysis cohort over those lost to follow-up. Nevertheless, the oversampling from lower socio-economic status areas means that this analysis population remains socio-economically diverse and acceptably representative of the overall maternity population at the time of recruitment (Scheil et al., 2015).

The benefits of breastfeeding cannot be understated. With the exception of the potential association between prolonged breastfeeding and ECC, no other negative health consequence of breastfeeding has been identified (Victora et al., 2016). Conversely, the positive health outcomes associated with breastfeeding are wide-ranging for the child, including reduced infectious morbidity and mortality, higher intelligence, fewer dental malocclusions, and likely protection against overweight and diabetes (Victora et al., 2016). Recent modelling by the WHO predicted that, if all children achieved current breastfeeding recommendations, 823,000 deaths per year could be prevented in children under 5 years, and a further 20,000 deaths per year from breast cancer prevented in their mothers (Victora et al., 2016). Benefits extend beyond reductions in death and disease, to socio-economic gains that could contribute to achieving many of the United Nations Sustainable

Development Goals (UNICEF, 2016; Victora et al., 2016) and provide potential economic savings of over US$300 billion globally (Rollins et al., 2016).

5.2.5 Conclusion

This study found no associations between sustained breastfeeding to at least 1 year of age, or night-time breastfeeding, and early childhood caries by 2–3 years of age. Given the wide-ranging benefits of breastfeeding, recommendations to limit breastfeeding are unwarranted, and current efforts to increase breastfeeding initiation and duration in line with global and national recommendations are critical for improved overall health. To reduce the prevalence of early childhood caries, improved efforts are needed to limit intakes of foods high in free sugars and take action on the social determinants of health.

Acknowledgements: The contributions of hospitals and the study participants are gratefully acknowledged.

Author Contributions: LD, JAS, DH, AJS, and MT designed the SMILE study; JAS, LD, DH and GD conducted the research for this study; GD and AM analyzed the data; GD, JAS and AB wrote the paper; GD had primary responsibility for the final content. All authors read and approved the final manuscript.

Conflicts of Interest: The Authors declare that they have no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Sources of Support: The Study of Mothers' and Infants' Life Events affecting oral health (SMILE) was supported by a National Health and Medical Research Council Project Grant (GNT: 1046219). The authors would like to acknowledge the Australian Government Research Training Program Scholarship in supporting this research.

5.2.6 Supplementary Materials

Two supplementary tables are published with this article. Table 5.3 compares characteristics of those who completed the dental examination with the full recruitment cohort. Characteristics of the analysis cohorts were reported in the main results via Table 5.1. Supplementary Table 5.4 presents the multivariable models for ECC and dental caries at 2–3 years of age, with free sugars intakes removed from the model.

Table 5.3 Participant characteristics, SMILE cohort[1]

	All participants (*n* = 2181)			**Dental examination (*n* = 1039)**			
	n	**mean**	**SD**	***n***	**mean**	**SD**	***p***
Mother's age at birth (years)	2178	29.8	5.4	1038	30.5	4.9	<0.001
Breastfeeding duration (weeks)	1450	36.6	32.2	1028	43.0	33.0	<0.001
Child's birthweight (g)	2083	3356	572	1025	3379	569	0.071
	n	**%**		***n***	**%**		
Breastfeeding duration							<0.001
0 - <1 months (minimal)	208	14.3		101	9.8		
1 - <6 months	465	32.1		280	27.2		
6 - <12 months	316	21.8		240	23.3		
≥12 months (sustained)	461	31.8		407	39.6		
Feeding to sleep aged 1 year							<0.001
Mixed feeding	28	2.3		22	2.4		
Bottle but not breast feeding	396	33.0		262	29.1		
Breast but not bottle feeding	246	20.5		219	24.3		
No feeding to sleep	530	44.2		398	44.2		
Free Sugars intakes [2]							<0.001
Noncompliant	171	14.4		135	13.8		
Partially noncompliant	250	21.0		225	22.9		
Semi compliant	391	32.9		334	34.0		
Compliant	378	31.8		287	29.3		
Mother's Education							<0.001
High school / vocational	1136	54.0		455	44.2		
Some university & above	968	46.0		574	55.8		
IRSAD [3]							<0.001
Deciles 1–2	462	22.2		165	16.0		
Deciles 3–4	446	21.4		220	21.4		
Deciles 5–6	390	18.7		209	20.3		
Deciles 7–8	385	18.5		198	19.2		
Deciles 9–10	398	19.1		237	23.0		

[1] Study of Mothers' and Infants' Life Events affecting oral health. Characteristics of all participants, and those who completed the 2–3 year-old dental examination. *p* values compare participants who completed vs did not complete dental examination; using t-test (continuous) or Pearson Chi Square test (categorical).

[2] Free sugars intakes compliance with the WHO (2015) guideline categorised as noncompliant (free sugars > 10% of energy on both occasions), partially noncompliant (> 10% on one but not both occasions), semi-compliant (< 10% on both occasions, but > 5% on at least one occasion), and compliant (< 5% on both occasions).

[c] IRSAD: Index of Relative Socio-economic Advantage and Disadvantage where decile 1 is most disadvantaged and 10 is most advantaged (ABS, 2013).

Table 5.4 Early childhood feeding practices and dental caries at 2–3 years of age; models without sugars

	ECC Prevalence [1]			
	Model 1: Breastfeeding duration (*n* = 965)		**Model 2: Feeding to sleep (*n* = 866)**	
	***PR* [2]**	***95% CI***	***PR***	***95% CI***
Breastfeeding duration				
0 - <1 months (minimal)	0.71	0.30, 1.68		
1 - <6 months	0.84	0.47, 1.50		
6 - <12 months	1.00			
≥ 12months (sustained)	1.38	0.84, 2.26		
Feeding to sleep aged 1 year				
Mixed feeding			1.86	0.66, 5.26
Bottle but not breast feeding			0.75	0.44, 1.30
Breast but not bottle feeding			1.21	0.73, 2.01
No feeding to sleep			1.00	
Mother's Education				
High school / vocational	0.94	0.63, 1.42	0.83	0.53, 1.30
Some university & above	1.00		1.00	
IRSAD [3]				
Deciles 1–2	2.10	1.08, 4.08	2.09	0.98, 4.45
Deciles 3–4	1.98	1.06, 3.70	2.31	1.17, 4.57
Deciles 5–6	1.33	0.67, 2.60	1.43	0.68, 2.98
Deciles 7–8	1.71	0.89, 3.26	1.80	0.88, 3.69
Deciles 9–10	1.00		1.00	

[1] Presence of Early Childhood Caries, based on the presence of decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth (Phantumvanit et al., 2018).

[2] PR: Prevalence Ratio, 95% CI: Confidence Interval; derived using multivariable regression

[3] IRSAD: Index of Relative Socio-economic Advantage and Disadvantage, where decile 1 is most disadvantaged and 10 is most advantaged (ABS, 2013).

Chapter 6 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 Overview

This final chapter commences with an outline of the research objectives that were achieved and summarises the related findings. The remainder of the chapter explores the interpretation and translation of the findings of this thesis, informed by the determinant analysis undertaken in Chapter 2, and aligned to the common risk factor approach to health (Sheiham & Watt, 2000; WHO, 2017c). Recommendations for practice, for public health action and for further research into breastfeeding and ECC are made, followed by some brief concluding remarks.

6.2 Review of Thesis Objectives and Findings

Table 1.1 (p. 3) presented the research aims and objectives of this thesis. A summary of how each aim and its supporting objectives were met is discussed below. This is followed by a discussion of the strengths and limitations of this work.

6.2.1 Primary Aim: Infant Feeding and Early Childhood Caries

The primary aim of this research was to *investigate the association between 1) prolonged and 2) night-time breastfeeding and early childhood caries*. This was met by objectives 1 and 5, which were to:

> 1. Critique the current evidence for the associations between breastfeeding and ECC, in order to ascertain mechanisms of action, likely confounders in the causal pathway and current limitations of research to date;

and,

> 5. Assess the relationship between infant feeding practices and ECC, controlling for key dietary and demographic factors, in a cohort of Australian children experiencing universal fluoride coverage.

The critique of the current evidence base (Chapter 2) identified that there are plausible mechanisms of action by which breastfeeding practices may disrupt caries balance and promote demineralisation, however there are also mechanisms by which breastfeeding may promote remineralisation and support a healthy oral microbiome. Considerations of the alternatives to breast milk across the first 2 years of life demonstrated that infant formula is no less caries-promoting than breast milk, and therefore in the first year of life at least, breast is still best. A determinant analysis of ECC identified important proximal and distal risk factors, including diet quality, oral health practices, exposure to publicly fluoridated water, socio-economic position, and public health actions. Finally, a review of recent studies that have investigated the relationship between infant feeding practices and ECC identified a range of study design limitations, presenting key considerations for future research, and highlighting the strengths of the Study of Mothers' and Infants; Life Events affecting oral health.

The work related to objective 1 also informed the dietary assessment activities of the secondary aim, as the lack of robust dietary measures is a key gap in the research to date. This was needed to supply the free sugars variable used to meet objective 5 and the primary aim.

The assessment of the relationship between infant feeding practices and ECC (Chapter 5) concluded that neither breastfeeding beyond 1 year of age (PR 1.42, 95% CI 0.85–2.38, relative to breastfeeding between 6 and 12 months); nor breastfeeding to sleep at 1 year of age (PR 1.12, 95% CI 0.67–1.88, relative to no feeding to sleep) were associated with higher prevalence of ECC at 2–3 years of age. Instead, having a free sugars intake greater than 10% of energy at 1 and 2 years of age (PR 1.97, 95% CI 1.13–3.44, relative to less than 5% at both time points), and being in the lowest category of socio-economic position at birth (PR 2.15, 95% CI 1.08–4.28, relative to the highest category) were associated with higher prevalence of ECC at 2–3 years of age.

These findings are published in the American Journal of Clinical Nutrition (Q1; 2018 impact factor: 6.568).

6.2.2 Secondary Aim: Dietary Assessment Tool

The secondary aim was to *develop and assess the relative validity of a dietary assessment tool to capture the leading dietary contributors to dental caries risk in Australian pre-schoolers aged 18–30 months*. This was met by objectives 2 and 3, which were to:

> 2. Develop a dietary assessment tool to assess intakes of total and free sugars from major food and beverage sources, fluoride from non-water sources and other key foods relevant to dental caries in Australian pre-schoolers aged 18–30 months via a proxy report;

and,

> 3. Investigate the relative validity of the tool developed in objective 2, for total sugars, free sugars and fluoride against repeat 24-hour recalls, using external calibration methods

The tool was developed and investigated for relative validity in a cohort of Australian mother-child dyads (*n* = 95, Chapter 3). The combined findings of a range of relative validity and repeatability tests (see 3.3.3, p. 90) suggest that the SMILE-FFQ is considered acceptable for ranking participants by free sugars intakes in observational studies of Australian toddlers. These findings were published in the International Journal of Environmental Research and Public Health (Q2; 2018 impact factor: 2.468), and the FFQ was subsequently administered to the SMILE cohort at 2 years of age. The sugars data were then used to achieve the primary and tertiary aims.

Additional investigations determined that the current version of the SMILE-FFQ is not valid for assessing fluoride intakes (see 3.4.2, p. 104), and adaptations were made for future use, with an updated SMILE-FFQ administered to the SMILE cohort at 5 years of age (outside of the scope of this thesis).

6.2.3 Tertiary Aim: Dietary Assessment and Reporting

The tertiary aim was to *describe the status of free sugars in the diets of a cohort of Australian children aged 0–2 years*. This was met by objective 4, which was to:

> 4. Investigate intakes and food sources of free sugars at 1 and 2 years of age; compare findings to WHO intake recommendations and national data; and explore socio-demographic determinants of high free sugars consumption.

Among children in the SMILE cohort (Chapter 4), free sugars intakes were relatively modest at 1 year of age, as children were still transitioning to the family diet, with free sugars contributing 3.6% (SD 2.8, IQR 1.6–4.8) of energy. Commercial infant and toddler foods emerged as a major source of free sugars, contributing 27% of free sugars intakes at 1 year of age. By the time the cohort reached 2 years of age, 71% of children were exceeding the WHO recommendation that less than 5% of energy come from free sugars, with 38% exceeding the < 10% recommendation. The major food sources of free sugars at this age were similar to those seen for older children in the National Nutrition and Physical Activity Survey, although commercial infant and toddler foods were still influential, contributing 15% of free sugars (ABS, 2016b). At both time points, socio-economic position was a determinant of high free sugars consumption. These findings were published in the Journal of Maternal and Child Nutrition (Q1; 2018 impact factor: 3.305), and in Nutrients (Q1; 2018 impact factor: 4.171).

Additional publications reporting the dietary intakes of the SMILE cohort are listed in 1.6 *Dissemination and Awards* (p. 8).

6.2.4 Strengths and Limitations of This Research

The Study of Mothers and Infants' Life Events affecting oral health addressed many of the design limitations of previous studies (see 2.6, p. 66). Taking a prospective approach, participants were followed from birth, and observed using thorough and validated methods for the outcome, exposure and confounding variables. The oral examinations at 2 years were conducted by dentists from the Australian Research Centre for Population Oral Health who were trained in standard epidemiological examination and reporting methods. The risk of recall bias was reduced by administering questions about oral health and breastfeeding practices prospectively, at five time points across the first 2 years of life, using questions from national oral health and infant feeding surveys.

The strengths and limitations of the dietary assessment methods used within SMILE are discussed in Chapter 3 (see 3.2, p. 72) and Chapter 4 (see 4.3.4, p. 131 and 4.4.4, p. 152). The use of estimated energy requirement (EER) rather than energy intake (EI) to evaluate percentage of energy from free sugars at 2 years of age is a potential source of bias in our findings (see 4.4.4, p. 152). Preliminary data analysis for the primary aim investigated free sugars intakes in grams as tertiles as well as compliance with the WHO (2015) guideline. The models produced similar results, so compliance with the WHO guideline was selected as the variable to retain for reasons of clinical significance, translation and pooling for meta-analysis (see 5.2.4, p. 178). At 1 year of age, the EER and EI were considered substantially different from one another in approximately 15% of participants (see 4.3.3, p. 124), however this could be due to inaccuracies in the EER, the EI, or both; and so this finding should not be extrapolated to EER used at 2 years of age.

Overall, the dietary assessment methods were as robust as was practical for a study of this size, within the budgetary constraints, and more comprehensive than most dental studies to date (see 2.5.2.1, p. 63). We considered issues of subject and researcher burden, and precision and accuracy in the design of the materials, and are satisfied that the resulting dietary data are of a reliable quality for use in SMILE analyses.

The strengths and limitations of the outcome investigation are discussed in Chapter 5 (see 5.2.4 p. 178). A key limitation of the findings presented here is the low prevalence of breastfeeding at 2 years of age (9%). The review by Moynihan and colleagues (2019) identified that the association between prolonged breastfeeding and ECC was only present when breastfeeding continued beyond the second year of life, but not if it ceased between 1 and 2 years. Combined with the relatively low prevalence of ECC in the cohort (10%), the number of children who were positive for ECC and breastfed at 2 years was small. These findings, therefore, support the hypothesis that breastfeeding duration to at least 1 year of age is not associated with increased ECC risk, but do not contribute to the evidence base for whether the risk is increased when breastfeeding continues beyond 2 years.

Another notable limitation was that we were unable to investigate whether access to fluoridated mains water mediated the effect of breastfeeding on caries risk (see 2.4.3, p. 54). Most Australians (89%) live in fluoridated areas, with those living in capital cities more likely to have access to fluoridated water than those in regional areas (Crocombe et al., 2016; NHMRC, 2017c). Our study participants all lived in the greater Adelaide area at the time of recruitment, reflecting the fluoride exposure experienced by the majority of Australians. Our findings are therefore generalizable to Australian children who have access to fluoridated water, particularly those living in Australian capital cities.

A potential source of bias is the selection of variables for inclusion in the final model. The directed acyclic graph (DAG) was determined *a priori*, based on the recent literature (Akinkugbe et al., 2016; Peres et al., 2018). Peres et al. (2018) highlight the importance of selecting appropriate confounding factors so as not to over- or under-adjust the model. The authors recommend excluding tooth brushing and other oral health practices from a DAG for breastfeeding and dental caries, noting that socio-economic position is likely to be the driver of associations between oral health practices and breastfeeding. Socio-economic position was included in the model, which was explored both with and without free sugars as a mediator (see 5.2.3, p. 1765.2.6). Nevertheless, it is possible that additional confounding by some of the determinants discussed in Chapter 2 have gone unadjusted for.

The dental examinations were conducted when the children were slightly younger than the recommended window of between 3 and 6 years of age. This likely explains, in part, the low caries prevalence in the cohort. A second round of dental examinations in SMILE has just concluded; conducted after the child's fifth birthday. Future investigations of breastfeeding and ECC will be strengthened by the anticipated higher caries prevalence at this age, and may be able to include severe ECC as an additional outcome variable, subject to the prevalence in the cohort. Free sugars intakes have also been assessed at 5 years of age, via re-administration of the SMILE-FFQ to provide a third free sugars data point. This additional investigation will not, however, resolve the limitations of short breastfeeding duration and universal fluoride coverage in this cohort.

This work is further limited by our treatment of breastfeeding as a singular practice. We selected duration of breastfeeding as our explanatory variable, using the WHO (2008) definition of 'any breastfeeding'. Other considerations such as exclusivity or amount of breast milk consumed, and frequency of feeds throughout the day were not included in our analysis. In addition, greater breastfeeding is associated with less formula feeding, particularly in the first 6 months of life, which affects caries balance in ways beyond differences in sugars intake (see 2.4.1.4, p. 40).

For example, children who consume formula reconstituted with fluoridated tap water have much higher fluoride exposure than those predominantly breastfed or those fed with formula reconstituted with non-fluoridated tap water (Ha et al., 2019; NHMRC, 2017a). Recent studies have attempted to improve on this through the use of Marginal Structural Models, which account for time-dependent confounding (Chaffee et al., 2014; Peres et al., 2017). This approach will be explored in the SMILE 5 year investigations, data permitting.

6.3 Translation of Findings: Taking a Common Risk Factor Approach

The common risk factor approach to chronic disease prevention is based on the premise that a significant proportion of chronic disease risk is attributable to a shared set of environmental factors and individual health behaviours (Sheiham & Watt, 2000; WHO, 2003a; WHO, 2017c). Common risk factors include diet quality, smoking, alcohol and the social determinants of health (Peres et al., 2019; Watt et al., 2019). Prevention initiatives that target these risk factors may have widespread effects across a range of disease outcomes. A diverse portfolio of strategies is needed, ranging from policy and legislation, to community action and health education (Sheiham & Watt, 2000; Watt & Sheiham, 2012).

Guidelines for populations, policy and practice should be informed by the common risk factor approach, to ensure alignment between health promoting messages for the prevention of all chronic diseases (Peres et al., 2018; Sheiham & Watt, 2000). Messages to the general public about breastfeeding must, therefore, represent overall conclusions from weighing up risks and benefits for chronic disease prevention as a whole (Phantumvanit et al., 2018; Victora et al., 2016). The vast majority of breastfeeding in Australia and globally occurs in the first 2 years of life, during which time the impacts on health are immense and entirely positive (COAG Health Council, 2019; Victora et al., 2016). During this period, breastfeeding reduces ECC risk in the first 6 months, and does not increase it if continued up to approximately 2 years of age (Moynihan et al., 2019; Phantumvanit et al., 2018; WHO, 2017c). Even after the second year of life, it appears that socio-economic position, fluoride exposure and free sugars intakes are the more pertinent factors in reducing caries risk than breastfeeding (Ha et al., 2019; Phantumvanit et al., 2018).

In light of these findings, and given the unequivocal and extensive benefits of breastfeeding, population messages about breastfeeding should not be confused by caveats relating to potential caries risk. This is particularly pertinent in populations where it is uncommon for children to be breastfed beyond the age at which ECC risk may be elevated, and whose overall health outcomes would benefit from increasing, not decreasing, breastfeeding duration. Instead, where a child's caries risk is elevated, health professionals should work in partnership with the parent/s to explore risk factors in the context of their lived experience, and develop an approach that incorporates their unique assemblage of health beliefs, motivators and barriers (Peres et al., 2018).

It may be appropriate for those nations that experience high ECC prevalence and long breastfeeding duration to provide population-level advice for reducing caries risk when breastfeeding continues beyond 2 years of age. However, this should be carefully considered within the common risk factor approach to health, and incorporated into an integrated strategy that addresses a wide range of ECC risk factors (Watt et al., 2019; WHO, 2017c). Recommendations to limit intake of foods high in free sugars, choose fluoridated tap water as the main drink, brush and floss teeth twice per day and visit the dentist regularly, commencing in the first year of life should be implemented prior to introducing caveats about breastfeeding. As a nation that experiences inadequate breastfeeding durations (COAG Health Council, 2019), this is not necessary or appropriate for the Australian context.

With consideration of these conclusions, and the common risk factor approach to health, a set of recommendations for practitioners, public health action and future research are presented.

6.4 Recommendations for Practice

It is important that health professionals from all fields provide consistent, evidence-based recommendations regarding breastfeeding and ECC, and incorporate emerging evidence into revisions of their professional guidelines. A summary of recommended revisions to current, Australian practice guidelines within the dentistry and nutrition fields is provided. This is followed by a discussion of scope of practice and the role of these health professionals in reducing ECC and supporting breastfeeding, followed by recommendations for practitioner education. A short practice update for health professionals concludes this section. Target groups include dental health practitioners, but also dietitians, nutritionists, child health nurses, general practitioners and other medical and allied health professionals.

6.4.1 Best Practice Guidelines

Health messages for the general public should be as straightforward as possible, so that they are interpreted correctly and actioned easily (Peres et al., 2018). Current best practice guidelines are inconsistent, contradictory and at times, contentious (see 2.4.4, p. 55). Table 6.1 reviews the current, Australian national practice guidelines within the dentistry and nutrition fields, proposing revisions for future updates. Five general statements are provided, covering recommendations for breastfeeding, for reducing caries risk, for breastfeeding and ECC among nations with long and short breastfeeding durations, and for public health action to ensure a healthy food supply and improve the social determinants of health. These statements are then applied to the current Australian dietary and oral health guidelines, highlighting proposed changes. The general statements in Table 6.1 are also incorporated into the practice update (6.4.4, p. 206).

Joint statements

The Dietitians Association of Australia (DAA) and Dental Health Services Victoria have published a joint statement on oral health and nutrition, available in the public areas of both organisations' websites. The statement includes a two-page summary of the specific considerations for oral health in early childhood, all of which align with the general statements in Table 6.1, and promotes the Infant Feeding Guidelines (NHMRC, 2012a). Regarding breastfeeding and ECC, the document states

> "Breast milk is good for healthy teeth. Breast milk is the best form of nourishment for babies and is not associated with dental caries."
>
> (DAA and Dental Health Services Victoria, 2015, p. 7)

The joint statement includes a section summarising oral health practices for dietitians, and future revisions would benefit from a reciprocal section summarising nutrition practices for dentists. Furthermore, the statement is generally focused toward individuals, with a brief mention of priority groups, and would be strengthened by the inclusion of population-level considerations from a public health perspective.

Food and nutrition guidelines

A statement about the relationship between breastfeeding and ECC was not included in either the Infant Feeding Guidelines (NHMRC, 2012a) or the Dietary Guidelines for Australians (NHMRC, 2013). Both of these guidelines make recommendations about other risk factors for dental caries, however, in light of findings from the PROBIT study (Kramer et al., 2007), it was determined that there was insufficient evidence of an association to warrant inclusion at the time of review (C. Binns, personal communication, October 10, 2013). There are statements in both sets of guidelines about the increased caries risk associated with consuming food and drinks with added sugars, and low consumption of fluoridated tap water (NHMRC, 2012a; NHMRC, 2013). The Infant Feeding Guidelines also make a number of recommendations related to dental caries in early childhood, identifying practices that increase caries risk such as the vertical transition of cariogenic bacteria from mother to infant, putting the baby to bed with a bottle (regardless of contents) and providing a pacifier or bottle teat that has been dipped in honey or another sweet substance (NHMRC, 2012a).

Table 6.1 Breastfeeding and early childhood caries: Recommendations for practice guidelines

		General statements for breastfeeding and the prevention of ECC
S-1	Statement for breastfeeding	*The Australian Infant Feeding Guidelines state "encourage, support and promote exclusive breastfeeding to around 6 months of age" then "continue breastfeeding while introducing appropriate solid foods until 12 months of age and beyond, for as long as the mother and child desire" The World Health Organization also endorses exclusive breastfeeding for the first 6 months of age, but recommends that breastfeeding continues for "up to 2 years of age or beyond". The benefits of breastfeeding for the infant and mother are unparalleled, and continue well into the second year of life.*
S-2	Statement for caries prevention	*To reduce the risk of dental caries throughout life, adults and children should limit intake of foods high in free sugars, choose fluoridated tap water as the main drink, brush and floss teeth twice per day and visit the dentist regularly, commencing in the first year of life.* *Foods and drinks that are high in free sugars should not be given to children in the first 2 years, and sugars should not be added to complementary foods and drinks.*
S-3	Statement for breastfeeding and ECC: all nations	*Breastfeeding in the first 6 months of life can help prevent dental caries.* *Continued breastfeeding for the first 2 years of life does not increase the risk of dental caries.* Additional information for health workers: For nations in which breastfeeding beyond 2 years of age is uncommon; population-level recommendations to limit breastfeeding to reduce the risk of tooth decay are not required, and may detract from efforts to increase breastfeeding rates. For nations in which breastfeeding beyond 2 years of age is common; see additional statement S-3a. For individuals who breastfeed beyond 2 years of age from any nation; individualised messages to limit the frequency of breastfeeds, especially at night, may be appropriate. This advice should promote other risk factors for tooth decay (see S-2) prior to giving cautionary messages about breastfeeding, in consideration of the nutritional needs of the child, and the continued benefits of breastfeeding. Dental practitioners should encourage, support and promote breastfeeding in line with infant feeding guidelines. Dietitians should consider the oral health implications when giving individual advice about breastfeeding beyond 2 years. Public health actions are also needed to reduce the risk factors for tooth decay and improve the social determinants of health (see S-2, S-4 and S-5), including ensuring that individuals and communities have access to fluoridated mains water, a healthy food supply, health education and subsidised dental health services in childhood.

S-3a	Additional Statement for breastfeeding and ECC: nations in which breastfeeding beyond 2 years of age is common	*There is some evidence to suggest that, after the child's second birthday, reducing the frequency of breastfeeds, especially at night, may decrease the risk of dental caries. This negative effect of breastfeeding beyond 2 years can be reduced by following other recommendations to reduce the risk of dental caries, such as limiting intake of foods high in free sugars, choosing fluoridated tap water as the main drink, brushing and flossing teeth twice per day and visiting the dentist at least once per year from 1 year of age onwards. These risk factors should be assessed and the benefits of continued breastfeeding weighed up against the risk of dental caries, prior to providing cautionary statements about limiting prolonged breastfeeding.* Additional information for health workers Nations in which breastfeeding beyond 2 years of age is common should consider the coverage of fluoridated public mains water, population intakes of free sugars, prevalence of early childhood caries and the availability of subsidised dental health services prior to providing cautionary statements about limiting prolonged breastfeeding.
S-4	Statement for ensuring a healthy food supply	*Public health actions to ensure a healthy food supply for all people, including limiting access, availability and promotion of foods and beverages high in free sugars, are critical in reducing the prevalence of dental caries among children and adults. Such actions also include improving access, availability and promotion of core foods, which consist of whole grains, fruits, vegetables, legumes, nuts, eggs, fish, lean meat, milk products and their plant-based alternatives.*
S-5	Statement for action on the social determinants of health	*National actions targeting the social determinants of health are needed to reduce the prevalence of dental caries among children and adults, particularly among populations experiencing greater socio-economic disadvantage.*

Continued

Application to current Australian guidelines			
Guideline and organisation	**Scope**	**Alignment with general statements S1-S5[a]**	**Recommendations**
Infant Feeding Guidelines: Information for Health Workers National Health and Medical Research Council (2013)	Nutrition / Infant feeding	S-1 Aligned S-2 Aligned overall: discussion of oral health practices is absent S-3 **Absent** S-4 Adjacent: breastfeeding friendly environments, not about food supply S-5 **Absent**	Add S-3 to summary section on dental caries, and add S-3 & S-5 to background Chapter 1
Eat for Health: Dietary Guidelines for Australians National Health and Medical Research Council (2013)	Nutrition for children & adults	S-1 Aligned S-2 Aligned overall: discussion of oral health practices is absent S-3 **Absent** S-4 Aligned, though not specific to dental caries S-5 Aligned / adjacent: Appendix A discusses social determinants of health and nutrition status, though not specific to dental caries	Add S-3 to Guideline 4 (breastfeeding) Add S-5 to Appendix A
Joint Position Statement on Oral Health & Nutrition Dietitians Association of Australia and Dental Health Services Victoria (2015)	Dentistry & Nutrition for children & adults	S-1 Aligned S-2 Aligned S-3 Aligned S-4 **Absent** S-5 Adjacent: identification of priority groups, including "people who are socially disadvantaged or on low incomes"	Produce new section on population health, including S-4 & S-5, or add S-4 to background section 2 & S-5 to priority groups section 5.

Standards of Care Australasian Academy of Paediatric Dentistry (2005)	Paediatric Dentistry	S-1 Aligned S-2 Aligned S-3 **Absent / Adjacent**: statements about the benefits of breastfeeding, & that the Academy "does not suggest the risk of dental disease contraindicates breastfeeding of susceptible children". One slightly contradictory statement to modify demand & nocturnal breastfeeding S-4 Aligned overall; public health is briefly mentioned S-5 **Absent**	Revise document to reflect current evidence base. Add S-3 to breastfeeding section 1.5 Add S-4 to dietary section 1.6 Produce new section on social determinants, or add S-5 to summary section 1.1.
Policy Statements of the Australian Dental Association 2.1 – National Oral Health (2017); 2.2.2 – Community Oral Health Promotion: Diet & Nutrition (2017); 2.3.1 – Delivery of Oral Health: Special groups: Children (2018); 2.3.8 – Delivery of Oral Health: Special groups: Infants & Pre-School Children (2018)	Dentistry & Nutrition for children & adults	S-1 **Absent** from all ADA policy statements* S-2 Aligned S-3 **Absent** from all ADA policy statements* S-4 **Absent**: one Aligned statement recommending a national sugar tax (policy 2.2.2). S-5 Aligned: statement about universal access to dental health services (policy 2.1) & disadvantaged groups (policy 2.3.1) * Policy 2.3.8 refers to "appropriate bottle and breast feeding practices", but does not define or further specify	Produce a new policy statement for Community Oral Health Promotion: Infant Feeding. Add S-1 to policies 2.2.2 & 2.3.8 Add S-3 to policies 2.2.2, 2.3.1 & 2.3.8 Extend policy 2.2.2 to reflect S-4 Extend policies 2.1 and 2.3.1 to reflect S-5; add S-5 to policy 2.2.2

S – Statement; ECC – Early Childhood Caries

[a] Alignment with General Statements classified as Aligned (may be differently worded, but the same overall message/s are conveyed); Adjacent (though not directly on the topic, statements are made that are adjacent to the topic, implying alignment); Absent (no statement is made); or Contradictory (wording is in opposition to general statements). Note: no Australian guidelines had statements that were classified as contradictory.

Oral health guidelines

There are few current, publicly available, Australian dental guidelines that address ECC. Policy statements produced by the Australian Dental Association (2019) make brief mention of considerations for children, and both the Australasian Academy of Paediatric Dentistry and the Australia and New Zealand Society of Paediatric Dentistry link to the International Association of Pediatric Dentistry, and the American and European Academies of Paediatric Dentistry, in the absence of their own current guidelines.

The Australian Dental Association (ADA) policy statements do not mention breastfeeding, except in statement 2.3.8, covering the delivery of oral health to infants and pre-school children, which states,

> "Dental practitioners can advise parents and carers on issues such as oral hygiene; diet; appropriate bottle and breast feeding practices…"
>
> (ADA, 2018b, p. 1)

and,

> "Maternity and early childhood nurses should have access to information regarding oral hygiene, teething remedies, appropriate feeding practices, avoidance of disruption to normal growth patterns…"
>
> (ADA, 2018b, p. 2)

The statement does not define or further explain what is meant by the term "appropriate feeding practices". Breastfeeding is not mentioned in any of the other policy statements, including the overarching national oral health statement 2.1 (ADA, 2017a), statement 2.2.2, covering diet and nutrition in community oral health promotion (ADA, 2017b) nor statement 2.3.1, covering the delivery of oral health to children (ADA, 2018a). These policies should be adapted to include the general statements for breastfeeding and the prevention of ECC (Table 6.1) where appropriate. Given the inconsistency of current messages on this topic, it is proposed that a new policy statement be developed by the Constitution and Policy Committee of the ADA, covering infant feeding in community oral health promotion. In addition, the ADA is encouraged to partner with the Dietitians Association of Australia to adapt the joint statement produced with Dental Health Services Victoria into a national joint statement.

The Australasian Academy of Paediatric Dentistry (AuAPD) standards of care were last released in 2005, and no longer appear on the public areas of the Academy's website. These standards provided a balanced set of guidelines that considered both the benefits of breastfeeding and the harms of ECC, recognising that "Breastfeeding remains an emotive issue" (AuAPD, 2005, p. 8). A statement in support of the WHO and UNICEF breastfeeding guidelines was made. Regarding breastfeeding and ECC,

> "The Australasian Academy of Paediatric Dentistry does not suggest the risk of dental disease contraindicates breastfeeding of susceptible children."
> (AuAPD, 2005, p. 7).

and,

> "Ad libitum nocturnal breastfeeding should be modified in conjunction with nutritional and medical advice to decrease the frequency of exposures"
> (AuAPD, 2005, p. 7).

Future releases of revised standards of care should be updated to reflect the current evidence base about breastfeeding in the first 2 years of life, and further advancements in the field. They should be made publicly available in order to serve as a key resource for the broader child health community.

The guidelines set by the American and European Academies of Paediatric Dentistry, should also be revised to reflect the current evidence base for breastfeeding. Similarly to the Australasian associations, the International Association of Pediatric Dentistry (IAPD) link to these two organisations in the guidelines for clinical practice section of the IAPD website, therefore these two Academies are particularly influential on an international scale. The current guidelines from the American Academy of Pediatric Dentistry (2016) recommend against demand and night-time breastfeeding (see 2.4.4, p. 55). The European guidelines on the prevention of ECC, last revised in 2008, make no mention of breastfeeding whatsoever (European Academy of Paediatric Dentistry, 2008), however the Academy's more recent clinical practice guideline for the management of early caries lesions in children and young adults states:

> "The typical characteristics of ECC are numerous (non-)cavitated lesions in the primary dentition caused by high frequency or ad libitum bottle feeding with sugar-containing drinks/foods and/or breastfeeding."
> (Kühnisch et al., 2016, p. 4)

Materials from the World Health Organization are also internationally prominent. Statements in the WHO (2017c) Expert Consultation on Public Health Intervention against Early Childhood Caries align with the general statements in Table 6.1. The report includes a summary of the major findings of the Tham et al. (2015) systematic review of breastfeeding and ECC, including that ECC risk was reduced for those with more versus less breastfeeding in the first year of life. The report notes a possible higher risk of ECC among children exposed to prolonged and night-time breastfeeding, but still recommends that children are breastfed for up to 2 years and beyond, in line with the WHO breastfeeding guidelines (WHO, 2017c).

The general statements in Table 6.1 should be further incorporated into relevant state and local guidelines for health professionals, beyond the nutrition and dental communities. This includes materials produced by groups such as Dental Health Services Victoria (2010) and the New South Wales Ministry of Health (2014), and those of other professional member organisations including the Nursing and Midwifery Board of Australia; Maternal, Child & Family Health Nurses Australia, the Australian Medical Association and the Royal Australian College of General Practitioners. Written and audio-visual materials produced for the general public should ensure consistent messages are provided in print and electronic brochures, fact sheets, websites, and information distributed via social media.

6.4.2 The Role of Health Professionals

Access to health services is frequent in the first 2 years of life (Golenko et al., 2015; Hayes et al., 2019), during which time parents are exposed to a wide range of information, education and advice on many health topics. Parents report receiving inconsistent advice on infant feeding from health professionals, with some practitioners putting their own 'spin' on infant feeding guidelines, or instructing parents to introduce solids early as a proposed solution to a range of issues (Begley et al., 2019; Matvienko-Sikar et al., 2018). Conflicting information from health professionals leads to uncertainty regarding who to trust for nutrition information and advice (Harrison et al., 2018; Matvienko-Sikar et al., 2018), and in response, many parents choose to comply with social and cultural norms, and/or follow the advice of family and friends who have the lived experience of infant feeding (Begley et al., 2019; Harrison et al., 2017).

Health professionals have an important role to play in countering misinformation and building a sense of trust in the current, evidence-based guidelines (Begley et al., 2019; Walsh et al., 2015). It is important that, despite the ongoing discourse about the cariogenic potential of prolonged breastfeeding, all health professionals give consistent recommendations about oral health practices, and about infant feeding (Moynihan et al., 2018; WHO, 2003b). Health professionals from any discipline are qualified to promote the population level, evidence-based guidelines for healthy diets, such as the Australian Dietary Guidelines (NHMRC, 2013) and Infant Feeding Guidelines (NHMRC, 2012a), and for oral health practices such as the position statements of the Australian Dental Association (2019), the Australasian Academy of Paediatric Dentistry (2005) and the joint statement by the Dietitians Association of Australia and Dental Health Services Victoria (2015). Where appropriate, health professionals can use behaviour change techniques such as goal setting and motivational interviewing to help clients work towards their health goals across the common risk factors (Moynihan et al., 2018; Tinanoff et al., 2019). Additionally, health professionals have an important role to play in identifying patients who are ‘at risk’ and referring them to a trained specialist in the relevant area, such as a dietitian or a dentist (Adamski et al., 2018; Watt et al., 2019).

Any variations to population messages should be provided to individuals within the scope of practice of the professional; with the tailoring of oral health recommendations provided by dental practitioners, and dietary tailoring by nutritionists and dietitians. Therefore there is little evidence for dental practitioners to advise against breastfeeding under any circumstances; as population messages unequivocally promote breastfeeding, and individualised dietary advice is outside of their scope of practice. Instead, providing a referral to a dietitian for comprehensive dietary assessment may be an appropriate strategy. Conversely, nutritionists and dietitians must consider the oral health implications of dietary recommendations when giving tailored dietary advice, and ensure that messages about diet quality align with population messages for dental health.

In order to support the delivery of consistent, evidence-based guidelines to parents seeking advice on infant feeding, health professionals need education, training, and continuing professional development programs.

6.4.3 Education and Training

Lack of nutrition knowledge has been identified by medical professionals (Adamski et al., 2018), midwives (Arrish et al., 2017) and dentists (Polglass et al., 2019) as a key barrier to providing nutrition education to clients. Some practitioners report that their training programs had insufficient nutrition content, and many rely on self-directed learning outside of course content to gain nutrition knowledge (Arrish et al., 2017; Crowley et al., 2015). Additionally, many practitioners describe feeling a lack of confidence in translating the nutrition knowledge that they do have into relevant, achievable, client-centred advice (Adamski et al., 2018; Arrish et al., 2017).

To ensure evidence-based information is provided consistently across the health service sector, the common risk factor approach should be included in curricula for a wide range of health courses. Educational institutions can embed learning outcomes relating to the common risk factors within inter-professional education programs, in order to foster collaborative practice, and promote improved health systems and outcomes (WHO, 2010). Dental, medical, nursing and other allied health courses should consider including basic, population-level nutrition education, including the importance of breastfeeding into discipline-specific curricula. Similarly, it is important to train non-dental health providers in oral health promotion strategies throughout the life course (Tinanoff et al., 2019; Watt et al., 2019). These approaches require leadership in institutional curriculum design, and revisions to accreditation standards by professional organisations such as the Australian Dental Council (2016), Dietitians Association of Australia (2015), and the Australian Medical Council (2012).

The development of curriculum guidelines can assist educational institutions and professional bodies to embed this approach into both single- and inter-professional courses. The Australian National Breastfeeding Strategy (COAG Health Council, 2019, p. 41) lists the action to “Consider the development of a core curriculum, skills matrix and national competency standards”, within the action area pertaining to health professionals’ education and training, which, if enacted, will provide materials for use by Australian education institutions in future. In the meantime, the UNICEF UK Baby Friendly Hospital Initiative (2019) provide a set of breastfeeding-related learning outcomes for educational design, however the current versions do not mention the relationship between breastfeeding and ECC. More broadly, a Nutrition Competency Framework for Australian medical programs was developed as a collaboration between medical and nutrition professionals, and work to embed nutrition into medical and other health professional curriculum is ongoing (Nowson, 2015; Perlstein et al., 2017).

The majority of dental training remains in the biomedical paradigm that is focused on disease, rather than health (Watt et al., 2019). Training is dentist-centred and individualistic in nature, rather than considering community based models of care, in which a diverse workforce act to prevent chronic disease across the common risk factors (Watt et al., 2019). Even the health promotion domain of the Australian Dental Council (2016) Professional Competencies of the Newly Qualified Dentist is individualistic in nature, with no mention of public health or systems-based interventions. This approach must change, as the need to work upstream across the health sector is increasingly understood. Dental practitioners require training in advocacy and policymaking, and the development of skills in integrating oral health priorities into wider health care services. Future revisions to professional competencies and course curricula should ensure the emerging dental profession is equipped to practice within this new paradigm.

For practitioners already in the workforce, continuing professional development is mandatory for all health professions in Australia as part of the Health Practitioner Regulation National Law (Australian Government, 2010). Continuing professional development modalities include practice update materials (see 6.4.4), seminars and presentations, and the use of technology and new media in digital audio, audio-visual and short- and long-form written articles. These resources assist health professionals in maintaining currency of practice, and are reported as part of annual continuing professional development activities required for membership renewal with accrediting professional bodies.

To assist with the translation of these findings, a practice update for dental, nutrition and other interested health professionals is presented here.

6.4.4 Practice Update: Breastfeeding and Tooth Decay in Australian Children

Key messages

- Consumers receive conflicting messages from dental, nutrition and other health workers about the relationship between breastfeeding and early childhood caries (tooth decay)
- Australian studies support the international evidence that breastfeeding to 2 years of age does not increase the risk of early childhood caries; and that fluoridated water modifies the effect of breastfeeding beyond 2 years on caries risk
- There is some evidence to suggest breastfeeding beyond 2 years increases caries risk of children who do not live in areas with fluoridated tap water, however around 89% of Australians live in fluoridated areas, and very few breastfeed to 2 years or beyond
- High free sugars intake, low socio-economic position, poor oral health practices and a lack of access to fluoridated water are all key risk factors for early childhood caries
- Within Australia, where breastfeeding rates are well below recommendations and duration rarely reaches 2 years of age, the current recommendations of the Infant Feeding Guidelines remain appropriate
- To reduce the risk of dental caries throughout life, adults and children should be advised to limit intake of foods high in free sugars, especially in the first 2 years, choose fluoridated tap water as the main drink, and undertake oral health practices, such as brushing and flossing teeth twice per day and visiting the dentist regularly, commencing in the first year of life

Background

The impacts of breastfeeding practices on the prevalence of early childhood caries is an ongoing source of discrepancy within dental and nutrition communities. Studies have observed a protective effect of breastfeeding in early life relative to no breastfeeding, but greater prevalence of early childhood caries when breastfeeding is continued for longer durations (Moynihan et al., 2019; WHO, 2017c). The age and circumstances in which breastfeeding begins to have a detrimental effect on oral health are not fully understood. Three systematic reviews of infant feeding practices and early childhood caries have recently been published, each of which criticise the low-to-moderate quality of studies to date, particularly a lack of consideration of confounders (Cui et al., 2017; Moynihan et al., 2019; Tham et al., 2015).

In the absence of a consensus, practice guidelines from the dental and nutrition fields make contradictory recommendations with regard to prolonged and demand breastfeeding. While the benefits of breastfeeding are extensive and incontrovertible; dental caries is the most common non-communicable disease in both children and adults, and the health and social consequences can be substantial (Victora et al., 2016; Watt et al., 2019). It is important that practitioners give consistent recommendations about oral health practices and infant feeding.

This practice update positions two new Australian studies within the current, international evidence base, discusses the application of findings to Australian families, and makes recommendations for practice.

Key terms

Early childhood caries, Also referred to as dental caries, tooth decay, baby bottle caries (informal), nursing caries (informal), bottle rot (informal); "the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child under the age of six." (AAPD, 2016, p. 60).

Breastfeeding, The provision of human milk to a child, including from the mother or other family member, a breast milk donor or a wet-nurse; given via any delivery method, including directly from the breast, or expressed and given via a bottle, cup or feeding tube, or added to complementary foods and beverages (NHMRC, 2012a; WHO, 2008).

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." (WHO, 2015, p. 5).

New evidence from Australia

There are two recent, Australian studies of relevance to this update.

The National Child Oral Health Study 2012-14 was conducted more than 25 years after the previous national oral health survey. The cross-sectional study had a large, nationally representative sample of 24 664 children from across Australia, and found that around 80% of dental caries experienced by children aged 5–10 years occurred among children in the lowest 20% for socio-economic position. Secondary analysis also observed an association between early childhood caries and breastfeeding after 2 years of age, but only among children who did not live in areas with access to public water fluoridation.

The Study of Mothers' and Infants' Life Events affecting oral health is a birth cohort study of children born in the greater Adelaide area. Researchers found no associations between breastfeeding durations beyond 1 year and early childhood caries at 2–3 years of age, but noted that only 10% of children in the study were breastfed to 2 years or beyond. Additionally, all children lived in areas with access to public water fluoridation at the time of recruitment. The risk factors associated with early childhood caries in this cohort (n = 965) were high free sugars intake; and low socio-economic position.

These two studies support the international evidence that suggests breastfeeding in the first 2 years of life does not increase the risk of early childhood caries, but that breastfeeding beyond 2 years may increase caries risk for children living in non-fluoridated areas. These studies also affirm the existing evidence that high free sugars intake, low socio-economic position and a lack of access to fluoridated water are key contributing risk factors for early childhood caries.

Considerations for the Australian context

- Breastfeeding duration rates in Australia do not meet current guidelines. Around 30% of children are breastfed to at least 1 year, but many of these have ceased by 2 years of age. In the 2014-15 national health survey 16.5% of children aged 13–24 months reported currently receiving breast milk.
- Most Australians (89%) have access to fluoridated mains (tap) water, with people living in Queensland (76%) or outside of capital cities experiencing the lowest coverage.

- The intakes of foods high in free sugars by Australian children aged 2–18 years exceed recommendations, with an average of 13% of their energy intake coming from free sugars in the 2011-12 Australian Health Survey. There is no national data for children under 2 years, but those in the Study of Mothers' and Infants' Life Events affecting oral health consumed, on average, less than 4% of energy from free sugars at 1 year of age, which increased to greater than 10% at 2 years.
- Health inequality is rising in Australia, with the gap in health outcomes widening between people from higher and lower socio-economic position.

Recommendations for practice

Breastfeeding remains an unparalleled way to improve the health of individuals and communities. There is ample evidence to support the current recommendations of the Australian Infant Feeding Guidelines for Health Workers. Australians are advised to *"encourage, support and promote exclusive breastfeeding to around 6 months of age"* then *"continue breastfeeding while introducing appropriate solid foods until 12 months of age and beyond, for as long as the mother and child desire"* (NHMRC, 2012b, p. 3). The World Health Organization recommends that breastfeeding continues to 2 years of age or beyond.

Recommendations for adults and children to limit intake of foods high in free sugars should be promoted. The World Health Organization recommends that complementary foods should not contain any free sugars and that for children and adults less than 10%, or ideally less than 5% of energy come from free sugars. Nutrition education for parents should include how to read an ingredients list and nutrition information panel to identify sugars, and how to prepare complementary foods without free sugars. Public health actions to ensure a healthy food supply for all people, including limiting access and availability of foods high in free sugars, are critical in reducing the risk of tooth decay among children and adults.

Practitioners are advised to encourage the consumption of fluoridated tap water and provide education and support to counter misinformation about this evidence-based initiative. In addition to providing fluoride, this has the added effect of displacing sugar-sweetened beverages, a major source of free sugars in the Australian diet.

Oral health recommendations should align with the current guidelines set by the Australian Dental Association, including the promotion of twice-daily tooth brushing and flossing, and regular dental visits, commencing in the first year of life but no more than 6 months after the first tooth erupts. The Australian Government provides means-tested funding for basic dental services for eligible children aged 2–17 years via the Child Dental Benefits Schedule.

Continued efforts are needed to advocate for greater public health action to reduce health inequality in Australia. National actions targeting the social determinants of health are necessary to reduce the prevalence of dental caries, particularly among populations experiencing socio-economic disadvantage. Practitioners are invited to join organisations such as the Public Health Association of Australia, and lend their support to advocacy work of groups including Parents' Voice, Rethink Sugary Drink, and the Obesity Policy Coalition.

Collectively, these recommendations fall within the common risk factor approach to health, improving dietary patterns and health behaviours that reduce risk of the major chronic diseases facing Australians.

*** End of Practice Update ***

6.5 Recommendations for Public Health Action

The ECC determinants discussed in Chapter 2 are influenced by the state of public health in Australia. Policies surrounding water fluoridation, subsidised dental services and health insurance, food labelling and marketing and state-funded healthy eating campaigns all contribute to caries-related health behaviours and outcomes (Peres et al., 2019; Phantumvanit et al., 2018). In addition, the diet quality of young children, including increasing breastfeeding and decreasing exposure to foods high in free sugars, is an important area for public health action to improve health across a range of disease outcomes (NHMRC, 2012a, 2013). A summary of recommended public health actions for improving oral health and diet quality of children, including breastfeeding, is provided here.

In 2019, the Lancet series on oral health (Peres et al., 2019; Watt et al., 2019) and the Lancet commission report on the global syndemic of undernutrition, obesity and climate change (Swinburn et al., 2019) both presented similar arguments for the need for widespread systems change to halt the growing burden of disease. These topics, published independently of one another, identified many of the same drivers of rising health inequality, and highlighted the need for greater political action via more upstream public health approaches. Within the dental workforce, the clinically focused, interventionist paradigm hinders the progression of population-oriented strategies, and has been criticised for driving overly simplistic, downstream approaches to oral health care (Peres et al., 2019; Watt et al., 2019). In nutrition, substantial lobbying by the food agribusiness sector has been identified as a key barrier to political action (Sacks et al., 2018; Swinburn et al., 2019). Ongoing and consistent advocacy work is needed to drive policy change and bring about increased resource allocation to public health initiatives within the oral health, breastfeeding and greater nutrition disciplines, and more widely across the common risk factors.

6.5.1 Oral Health Actions

Public health actions play a critical role in halting the rise in oral diseases (Peres et al., 2019; Watt et al., 2019). The National Oral Health Plan 2015-2024 describes a range of strategies to improve oral health among adults and children (COAG Health Council, 2015). Funding models must be reshaped to target determinants that are further upstream in the disease prevention pathway and capitalise on the common risk factors (Peres et al., 2019; Watt et al., 2019).

Improvements to public mains water fluoridation schemes and the implementation of the Australian National Child Dental Benefits Schedule are considered public health victories, however more can be done to strengthen these programs (PHAA, 2018e). A national standard for access to fluoridated water should be developed, supported by a technical panel to advise and support state and local governments in aligning to the NHMRC recommendations (COAG Health Council, 2015; NHMRC, 2017b). All states and territories should continue to seek opportunities to progress towards universal coverage, aiming to provide fluoridated water to all communities with populations over 1000 people, and education and support for families living in non-fluoridated areas (COAG Health Council, 2015). Further public health actions include extending the National Child Dental Benefits Schedule to children under 2 years of age; promoting the program to improve uptake, particularly targeting families experiencing greater socio-economic disadvantage (ABS, 2017b; ADA, 2018a); and increasing private health insurance rebates for families on lower incomes (ABS, 2017b).

There are also unrealised opportunities to incorporate oral health into primary health care services, in order to strengthen prevention strategies, improve accessibility of services, and increase responsiveness to population needs (Mitchell et al., 2015; Watt et al., 2019). During early childhood, community or child health nurses provide primary care for a range of health areas, including basic oral health education and visual inspection of the mouth for dental disease (Commonwealth of Australia, 2011). Strengthening partnerships between child health nurses and community dentists can improve the primary oral health care provided and streamline the referrals process. As changes in approach to the healthcare system structures in Australia are implemented via the National Primary Healthcare Strategic Framework (Commonwealth of Australia, 2013) and Primary Health Networks Program (Commonwealth of Australia, 2018), there are opportunities to include dental services in primary health care that are currently not being leveraged. Advocacy work is needed to encourage policymakers to incorporate oral health into future primary health initiatives for both children and adults.

6.5.2 Monitoring and Surveillance

Ongoing population monitoring is critical for public health planning and policy development, for resource allocation, measuring outcomes, observing priority populations and conducting program evaluation and quality improvement activities (COAG Health Council, 2015; Swinburn et al., 2015; WHO, 2013a; WHO, 2016). At present, neither dental nor food and nutrition monitoring in Australia meets recommendations by public health authorities, however there has been some progress in recent years. One of the strategies outlined in Australia's National Oral Health Plan is the routine collection of population oral health data, including a national oral survey for adults and children every 10 years (COAG Health Council, 2015). Similarly, the Australian National Breastfeeding Strategy includes a monitoring and evaluation framework, which aims to provide ongoing national monitoring of breastfeeding trends, and regular monitoring of activities to protect, promote and support breastfeeding (COAG Health Council, 2019). Advocacy work is needed to ensure these strategies are actioned. There is no national nutrition strategy, so intentions for ongoing food and nutrition monitoring have not been set.

Within the food and nutrition system, there is a need to monitor the dietary intakes of populations, the composition of the food supply, food marketing strategies (particularly those directed at children), cost and affordability of foods, prevalence of food insecurity, and compliance of food companies to voluntarily-adopted public health initiatives (Pollard et al., 2015a; Sacks et al., 2019; WHO, 2016). There is no ongoing national monitoring in any of these areas, although some monitoring occurs by individual states and territories (Sacks et al., 2019). Attempts to improve food and nutrition system monitoring are hindered by the absence of national nutrition policy (Pollard et al., 2015a) substantial industry opposition, and generalised policy inertia (Swinburn et al., 2019).

The common risk factor approach can also be applied to population monitoring, whereby standardised monitoring systems for non-communicable diseases could be integrated with oral and nutrition monitoring programs (COAG Health Council, 2019; Watt et al., 2019). The 2011-13 Australian Health Survey obtained comprehensive population health information, including dietary intake data, which has been utilised across a wide range of settings (ABS, 2017a). The survey evaluation recommended that a regular schedule of health surveys be implemented, and identified oral health as an area for inclusion in future surveys (ABS, 2017a). To date there have been no commitments by government to action this recommendation, despite the strong positive evaluation results (ABS, 2017a; Calder et al., 2018). This lack of action reflects the wider deficits in population monitoring in Australia, which would benefit from an integrated and strategic approach, co-ordinated by a single government agency with ongoing funding and robust data linkage systems (ABS, 2017a; Calder et al., 2018; Commonwealth of Australia Productivity Commission, 2017).

6.5.3 Limiting Free Sugars Intakes

National actions to reduce intakes of free sugars are inadequate, despite the growing evidence base for what can work (PHAA, 2018d; Sacks et al., 2019; WHO, 2016). Several promising initiatives are under-implemented, taking a voluntary adoption or industry self-regulatory approach, including the front-of-pack Health Star Rating system (Commonwealth of Australia, 2019b) and the industry-led Responsible Children's Marketing Initiative (Mills et al., 2015a). In addition to the strategies identified below, there are many other policy actions that could be implemented in order to foster healthy food environments, across food composition, labelling, promotion, provision, retail, prices, and trade and investment (Sacks et al., 2019; Vandevijvere & Swinburn, 2017). A co-ordinated, whole-of-government approach to improving the diet quality of Australians is needed, underpinned by a national nutrition policy (PHAA, 2018b; Sacks et al., 2019). There is strong public support for government action to improve healthy food environments, and it appears to have increased in recent years (Miller et al., 2019).

Changes to Sugars Regulation and Labelling

Australia and New Zealand Food Standards must be regularly reviewed and updated to reflect the current food supply, evidence base and national and global public health recommendations (Lawrence et al., 2019). There are missed opportunities within food regulation and labelling to assist consumers in choosing foods low in free sugars. Some proposed changes to sugars labelling and the front-of-pack Health Star Rating system are currently under consideration, and advocacy work is needed to ensure the recommendations are fully implemented (PHAA, 2017b; PHAA, 2018d). In particular, free sugars should be included on the mandatory nutrition information panel, and all 10 recommendations of the independent Health Star Rating 5-year review report should be actioned, including revising the criteria for calculating the rating to more closely reflect the Australian Dietary Guidelines (Food Regulation Standing Committee, 2019; FSANZ, 2019b; mpconsulting, 2019).

Beyond the changes currently under consideration, ongoing advocacy to change the Health Star Rating system from voluntary to mandatory is needed, along with research and evaluation into the effects of the current changes (Jones et al., 2018; Moore et al., 2019; PHAA, 2017b). In addition, modelling demonstrates that differentiating between total and added or free sugars in the calculation criteria would improve the Health Star Rating's discrimination between core foods and energy-dense, nutrient-poor discretionary foods (Peters et al., 2017). The next Health Star Rating system review is recommended for 2024, during which there will be opportunities to advocate for further revisions to the algorithm used to calculate the rating of foods, particularly once free sugars has been added to nutrition information panels for all products (Mela & Woolner, 2018; mpconsulting, 2019; PHAA, 2017b).

At present, the Australia New Zealand Food Standards Code does not sufficiently regulate the use of free sugars in infant and toddler food products (see 4.4.4, p. 152). The *Food Standard 2.9.2 – Food for infants* is out of date with the current food supply and evidence base. In particular:

- The Standard only covers foods for children less than 1 year of age, whereas the infant and toddler food market now includes a wide range of products marketed to children aged from 4 months to 4+ years (IBISWorld Australia, 2017).
- Infant foods can be labelled as suitable from 4 months of age, contradicting the World Health Organization and the Australian Infant Feeding Guidelines, which both state that complementary foods are not suitable until around 6 months of age and should not be promoted to younger children (NHMRC, 2012a; WHO, 2017a).
- Many infant and toddler foods are sweetened with fruit juice in order to avoid the labelling requirements for added sugars (Dunford et al., 2015)

The current standard for infant foods should be revised to include foods marketed to children up to 5 years of age, rather than only those for children less than 1 year of age, and the minimum recommended age for infant foods, whether express or implied should be ‘around 6 months’. In addition, the WHO (2015) definition of free sugars should be used instead of the more ambiguous term added sugars, to close the current loophole that allows manufacturers to use fruit juice as a sweetener in products marketed as ‘no added sugar’. The implementation of these two changes would strengthen the current standard to ensure that all infant and toddler products containing free sugars at levels greater than 4g per 100g would need to be labelled as ‘sweetened’. This would affect a substantial proportion of infant and toddler food and drinks, which would promote reformulation and help consumers to make informed choices. For example, of the 187 infant and toddler foods we reviewed for SMILE (Appendix F), 23% (n = 43) contained more than 4g of free sugars per 100g; which was 61% of the foods that contained any free sugars (n = 71).

A further action is to implement a compositional requirement for free sugars in infant and toddler foods. Within this approach, a maximum free sugars concentration would be permitted, the same as the current approach to sodium in the Standard. The results of SMILE indicate that infant and toddler foods make up a substantial proportion of young children’s diets and contribute around one quarter of free sugars intakes of 1-year-olds, so this is an opportunity to substantially reduce exposure in early childhood (see 4.3, p. 118). It is likely that there would be significant industry opposition to this approach.

Curbing the Influence of Food Marketing and Media

Leading public health organisations recommend the adoption of:

> “a national co-ordinated approach to restrict exposure of children to unhealthy food and beverage promotion across multiple settings, including sport and recreation settings and those controlled or managed by Australian governments”
>
> (Sacks et al., 2019, p. 3).

In Australia, the Responsible Children’s Marketing Initiative takes a self-regulatory approach to reducing exposure of children to unhealthy food marketing, which is designed and operated by the food and advertising industries. It does not protect children from exposure to unhealthy food and beverage promotion, and has weakened in recent years (Mills et al., 2015a; PHAA, 2018a). There has been little action on this issue, however the Council of Australian Governments (2018) released a national interim guide to reduce children's exposure to unhealthy food and drink promotion, in advance of a more comprehensive approach after the next review of the Australian Dietary Guidelines. At only 2-pages in length, the document does not provide guidance for how to reduce children's exposure to unhealthy food and drink promotion, but instead lists the types of foods and drinks that are not recommended for promotion (COAG Health Council, 2018). Greater action is needed.

Early childhood feeding practices are also influenced by the promotion of complementary foods. The WHO *Resolution on Ending the Inappropriate Promotion of Foods for Infants and Young Children* was accepted by the World Health Assembly in 2016, and includes a range of recommendations for public health action (WHO, 2018). A rapid evidence review to inform the resolution reported that the marketing of complementary foods and drinks influences consumer knowledge, attitudes, preferences and behaviours towards infant and young child feeding, and has been linked to the early introduction of solid foods, early cessation of breastfeeding, reduction of breastfeeding exclusivity and displacement of home prepared foods and beverages (Smith et al., 2015; WHO, 2017a). Consumers want simple and reliable information on food labels, and many parents express confusion and uncertainty with regard to complementary feeding (Begley et al., 2019; Pollard et al., 2013; WHO, 2017a). An investigation of current marketing strategies employed by infant and toddler food manufacturers and their effects on consumer behaviour is needed. Special restrictions on the promotion of infant and toddler foods should be considered.

Using Fiscal Policy to Guide Purchasing Behaviour

A range of health-oriented food taxes have been implemented in countries other than Australia, with a sugar-sweetened beverage tax seeing significant action in recent years (Backholer et al., 2016a; Friel et al., 2015; WHO, 2016). The health, social and economic benefits of a sugar-sweetened beverage tax are strong, however industry opposition and a lack of political leadership are key barriers to implementation (Backholer & Martin, 2017; Duckett, 2018; PHAA, 2017a). These taxes place a small additional financial burden on households with low socio-economic position, but also bring about greater reduction in intakes of sugar-sweetened beverages in these populations (Backholer et al., 2016b; Lal et al., 2017). A concurrent strategy to subsidise healthy foods; particularly for low income households can help address this inequality (Friel et al., 2015; Lal et al., 2017). There has been no progress on this issue in recent years in Australia (Sacks et al., 2019). To date, neither of the major political parties has committed to implementing a tax on sugar-sweetened beverages, however the third-largest political party in Australia released a policy platform in 2016, supporting the implementation of a 20% tax (The Australian Greens, 2016).

Targeting Distal Determinants

Approaches also need to consider the more distal determinants of food and health inequality, through welfare and housing reform, education, employment and labour legislation and universal healthcare (Friel et al., 2015; WHO, 2011). There is growing recognition of the need to reform food systems to make them sustainable, healthier and more equitable (Swinburn et al., 2019). Actions to improve food security must address structural determinants within the food system, but progress is hindered by a lack of political engagement, driven in part by poor understanding of the determinants of food insecurity by those in leadership positions (Lawrence et al., 2013; Pollard et al., 2015a). This is reinforced by the lack of population monitoring, with inadequate measurement methods in *ad hoc* national surveys, which obscures the severity of the problem (Butcher et al., 2019; McKechnie et al., 2018).

This overall scarcity of public health nutrition action is underpinned by the absence of a national nutrition policy (DAA, 2019; PHAA, 2018c). A comprehensive, national policy would consider a wide range of nutrition issues, and align with the National Breastfeeding Strategy (COAG Health Council, 2019) and the upcoming National Obesity Strategy (Commonwealth of Australia, 2019a). A key barrier to success is the influence of groups with commercial interests, who undermine public health efforts to improve diet quality, including the development and implementation of policy (Cullerton et al., 2016; Sacks et al., 2018). Transparent processes are needed, with a strategy for managing conflicts of interest in order to reduce inappropriate industry influence on decision-making (PHAA, 2018c; Sacks et al., 2018; Swinburn et al., 2015; Swinburn et al., 2019).

6.5.4 Encourage, Support and Promote Breastfeeding

National strategies to improve breastfeeding rates in Australia have largely stalled, and as a result, Australia is ranked 95 out of 97 countries for breastfeeding policy and programs, using the World Breastfeeding Trends Initiative (WBTi) scorecard (WBTi, 2018, 2019). Nevertheless, there has been some recent progress, with the release of a National Breastfeeding Strategy (COAG Health Council, 2019), and an independent review of the complaints handling process for the Marketing in Australia of Infant Formulas: Manufacturers and Importers (MAIF) Agreement (Nous Group, 2017). The recommendations set out in the National Breastfeeding Strategy do not go far enough to protect families from industry influence, and insufficient commitment of political resources, including funding, hinders likelihood of success (Smith, 2018). There are many unmet opportunities for public health action to improve breastfeeding rates in line with national and international guidelines (Smith, 2018; WBTi, 2018; WHO, 2017b).

The inappropriate marketing and promotion of infant and toddler formula is a key barrier to meeting breastfeeding guidelines, and the World Health Organization has advised nations on reducing the effects of these promotion strategies for nearly 40 years (WHO, 1981, 2018). The current MAIF Agreement (Australian Government, 2016) is voluntary, self-regulated by industry, and does not fully align with the WHO (1981) International Code of Marketing of Breast Milk Substitutes [the WHO Code] (WBTi, 2018). The MAIF Agreement is inadequate, industry breaches are commonplace and substantial improvements are needed (Berry & Gribble, 2017; Nous Group, 2017; WBTi, 2018). Future revisions of the MAIF Agreement should improve alignment with the WHO Code and successive World Health Assembly Resolutions (WHO, 2019b), including provisions for complementary foods and toddler formula marketed for children over 1 year of age (Smith, 2018; WHO, 2017a; 2018).

The use of legislation to ensure industry compliance with the WHO Code would improve the protection of parents from confusing and inappropriate information by formula companies (WHO, 2018). In 2018, 136 out of the 194 countries that are signatories to the WHO Code had some form of legislation relating to the WHO Code (WHO, 2018). Most of these only incorporate a few aspects of the code, but 35 countries have legislation that covers all provisions of the WHO Code. Australia is among the 58 nations who have no legislative measures in place (WHO, 2018). Continued and consistent advocacy work is needed.

6.6 Recommendations for Future Research into Breastfeeding and Early Childhood Caries

Recommendations for future research into breastfeeding and ECC are discussed in Chapter 2 (see 2.5, p 57) and Chapter 5 (see 5.2.4 p. 178). In particular, cohort studies with a substantial proportion of the population breastfeeding beyond 2 years of age would strengthen the conclusions that could be drawn from the findings of these studies. Inclusion of participants living in both fluoridated and non-fluoridated areas would allow for investigation of the fluoride hypothesis (see 2.4.3, p. 54). Further areas of interest in the relationship between breastfeeding and ECC include the effects of frequency and timing of eating occasions on caries risk, and that of different types of breastfeeding at night, for example, a comparison between breast-sleeping (bed-sharing while breastfeeding throughout the night), versus giving a single breastfeed to sleep (see 2.4.1, p. 35).

Future studies should employ the methodological considerations outlined in Chapter 2 (see 2.5, p. 57) and summarised in Table 2.5 (p. 58). These include the use of a prospective study design of appropriate length to observe exposures and outcomes of interest, with data collected at key time points to capture important exposures. Data collection should employ validated oral and dietary assessment and reporting methods, aligned to internationally recognised definitions of ECC, breastfeeding, and free sugars. The presence of ECC should be measured when the child is between 3 and 6 years of age, and breastfeeding behaviours should be assessed comprehensively, within an overall investigation of infant feeding practices. Data analyses should adjust for relevant confounders and effect modifiers, including fluoride exposure, free sugars intakes and socio-economic position, identified using directed acyclic graphs.

Advancements in statistical methods provide opportunities for comprehensive modelling that accommodates a range of biases, including time-dependent confounding (Peres et al., 2018). For example, breast and formula feeding are inversely correlated, with formula feeding associated with the early introduction of solid foods (Scott et al., 2009). This is, in turn, associated with shorter breastfeeding durations and the early exposure to energy-dense, nutrient-poor foods (Koh et al., 2010), including those high in free sugars. Marginal structural modelling is a new approach to caries research, as it can distinguish between mediators and confounders, accounts for time-dependent confounding, and models a simulated RCT scenario (Chaffee et al., 2014; Peres et al., 2017). The appropriate selection of covariates remains critical, as marginal structural modelling is based on the assumption that unmeasured confounding is not present between the exposure, mediator/s and outcome (Peres et al., 2017).

Beyond breastfeeding, the investigation of ECC risk by compliance with the WHO < 5% and < 10% free sugars recommendations would help elucidate the lower level of no effect, strengthening the evidence base for future revisions of the WHO (2015) sugars guidelines (Moynihan & Kelly, 2014; Sheiham & James, 2014). Additionally, further research is needed into the social determinants of ECC, with a focus on identifying and evaluating interventions that reduce the inequality of disease burden (COAG Health Council, 2015; WHO, 2011).

Finally, research into current perceptions of Australian parents and healthcare providers regarding breastfeeding and ECC, along with how these views translate to behaviour is needed. This would identify key sources of misinformation, assist with the development of population messages around breastfeeding and oral health, and inform the prioritisation of public health actions. Translation to practice would be further strengthened by intervention research, including modelling studies that show the economic, social and healthcare benefits of investing in public health nutrition.

6.6.1 Dietary Assessment for ECC Research

Recommendations for future dietary assessment research in pre-schoolers are briefly discussed in the publications of Chapter 4 (see 4.3.4, p. 131 and 4.4.4, p. 152). Although the methods employed by SMILE were of higher rigour than most studies to date that have investigated breastfeeding and ECC, there are still many areas for future development, and opportunities to incorporate emerging dietary assessment methodologies into future research.

Nutrient composition data

Intakes of free sugars have become simpler to analyse since the release of a free sugars database compatible with AUSNUT2011–13 (FSANZ, 2016). Future updates to Australian nutrient composition data should integrate free sugars, and include a wider range of commercial infant and toddler foods, particularly if national nutrition monitoring is extended to children younger than 2 years of age. Improved monitoring of the infant and toddler food supply is needed.

The World Health Organization (2015) definition of free sugars is comprehensive, however there are uncertainties in how it should be applied to some infant and toddler foods. For example, infant fruit and vegetable purees were coded as not containing free sugars in this research, however it is unclear whether the intrinsic sugars provided by the whole fruit have become free sugars during the manufacturing process, as they do for fruit juice. Research is needed to investigate the effect of commercial and home-made fruit purees on caries development, compared to fruit juice and whole fruit, using both *in vivo* and *in vitro* methods.

The addition of fluoride to Australian nutrient composition data would also improve the quality of dietary assessment in dental research. A substantial investment of time and financial resources to analyse the Australian food supply would be required in order to produce a reliable dataset. Fluoride is not of substantial interest to other areas of nutrition, therefore it is a lower priority than free sugars, and progress is slower.

An alternative to nutrient-based dietary assessment is dietary pattern analysis, which has the potential to capture the impacts of overall diet quality on caries risk (Chaffee et al., 2015). This approach reflects patterns of eating more comprehensively than a reductionist nutrient analysis, allowing for the interrelated effects of multiple nutrients and non-nutrient compounds within foods to be captured (Reedy et al., 2017; Reedy et al., 2018). As an emerging field, a shared conceptual framework has not yet emerged, and current approaches are heterogeneous, making comparison between studies difficult (Reedy et al., 2018). Further research is needed to standardise terminology and methods used for dietary pattern assessment and statistical analysis (Reedy et al., 2018). Future dietary pattern analysis methods could be applied to dental research, considering the frequency and timing of food and beverage intakes, in addition to diet quality.

Measurement methods

The SMILE-FFQ filled a gap in dietary assessment methods, allowing free sugars intakes to be assessed in Australian toddlers for the first time. Although food frequency questionnaires are considered lower subject burden than short term, total diet measures, such as a food record or repeat 24 hour recalls (NIH & NCI, 2018), there are still opportunities to improve their usability to maximise response rates. In the SMILE cohort, the FFQ had a higher response rate (1057 complete FFQs) than the 2-day estimated food record (835 returned complete), but not the 24-hour recall administered via telephone interview (1165 complete). At 89-items, the SMILE-FFQ may be seen by some study participants as long and tedious, especially if they are asked to complete it at the same time as other study questionnaires (as was the case in SMILE). In future, the development of a short screener version of the SMILE-FFQ, accompanied by validity testing, would provide an alternative method for assessing free sugars. This may be particularly useful to future dental studies that lack resources or nutrition expertise. There are also opportunities for the tool to be made available for use in community nutrition, dentistry or medical practice, or as an online self-assessment tool for the general public.

The Automated, Self-Administered, 24-hour recall (ASA24) has recently emerged as an alternative to the interviewer-administered 24-hour recall (NIH & NCI, 2018). It follows a similar multi-pass method to that which was adapted for SMILE (see 3.2.1, p. 73) but with lower research burden due to the automated administration. A large-scale validation study in the US found that for almost all of the 20 nutrients and food groups investigated, including added sugars, the ASA24 performed comparably to an interviewer-administered 24-hour recall, but with lower attrition, and was the preferred method by 70% of respondents (Thompson et al., 2015). An Australian version has been adapted from the original by the Institute for Physical Activity and Nutrition in collaboration with the US National Cancer Institute (Deakin University, 2019). To date, no version of the ASA24 has been validated for the proxy reporting of young children, nor does the current Australian version report free sugars.

Advances in technology are yielding new, image-assisted and image-based methods to collect dietary intake data (Boushey et al., 2017b; NIH & NCI, 2018). Wearable video cameras allow for passive provision of data by participants, and may assist with traditional self-report methods such as the 24-hour recall (Boushey et al., 2017b; Gemming et al., 2015). Handheld devices such as smartphones may also be used to assist traditional methods, or, with support of a mobile application such as the mobile Food Record (mFR), can be used as a standalone approach (Boushey et al., 2017a; Boushey et al., 2017b). The app guides participants to photograph their food and drink at the time of eating, and the image is automatically uploaded to a server where either an automated program or trained analyst reviews the images for dietary assessment (Boushey et al., 2017a; Boushey et al., 2017b). The majority of the research in this area has been among adults and adolescents, but validation studies with younger children are beginning to emerge (Aflague et al., 2015). Given the age of our study participants, a caregiver would still be required to take the images, and the high plate waste (with wide dispersion) will be a substantial barrier to portion-size estimation, particularly among systems that use an automated method. Ongoing technological advancements will provide solutions to these challenges in future (Boushey et al., 2017b).

6.7 Concluding Remarks

The work of this thesis has investigated associations between infant feeding practices and early childhood caries, following a cohort of Australian pre-schoolers for the first 2 to 3 years of their life. The methodological design of SMILE was rigorous, building on the strengths and limitations of similar studies, in order to further the current understanding about this issue. The conclusions presented here give clarity that, within Australia at least, recommendations to limit breastfeeding as a means for reducing ECC are not appropriate. Instead, a range of strategies are highlighted to limit intakes of foods high in free sugars, address socio-economic determinants, and strengthen community access to fluoridated mains water and oral health services.

The development and validity testing of the SMILE-FFQ was also well-informed by the literature, in terms of questionnaire development, study design and statistical methods. The resulting SMILE-FFQ fills a gap in the availability of suitable dietary assessment tools, allowing free sugars intakes to be assessed in Australian toddlers for the first time.

The use of robust dietary assessment methods is a strength of SMILE, and the resulting intake data fills a gap in dietary monitoring and surveillance, by reporting free sugars intakes of Australian children at 1 and 2 years of age. These investigations strengthen the existing evidence base that indicates dietary behaviours are influenced by social determinants, and highlight the substantial contribution of commercial infant and toddler foods to the diets of young children. This is an area of the food supply that has grown rapidly in recent years, and this research brings new awareness of these products and the need for improved food standards, and revisions to national monitoring and surveillance methods.

This thesis includes an interpretation of findings that takes a broader perspective (Chapter 6), reflecting the proximal and distal determinants of ECC that were identified by critical analysis of the literature (Chapter 2). A critique of key public health actions is included, recognising that widespread systems change is needed to halt the growing burden of chronic disease in Australia and globally. Overall recommendations describe a range of opportunities for practice, public health and future research, within the dental and nutrition fields and the wider health sector.

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Appendix B ETHICS APPROVALS

Curtin University Human Research Ethics Committee Reciprocal approval for the Study of Mothers' and Infants' Life Events affecting oral health.

Curtin University

Memorandum

To	Professor Jane Scott, School of Public Health
From	Professor Stephan Millett, Chair, Human Research Ethics Committee
Subject	Protocol Approval **HR 155/2013**
Date	10 October 2013
Copy	Ms Gemma Devenish, School of Public Health

Office of Research and Development
Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for your application submitted to the Human Research Ethics Committee (HREC) for the project titled "*Study of Mother's and Infant's Life Events Affecting Oral Health (SMILE)*". The Committee notes the prior approval by Southern Adelaide Clinical Human Research Ethics Committee (50.13) and has reviewed your application consistent with Chapter 5.3 of the *National Statement on Ethical Conduct in Human Research.*

- You have ethics clearance to undertake the research as stated in your proposal.
- The approval number for your project is **HR 155/2013.** *Please quote this number in any future correspondence.*
- Approval of this project is for a period of four years **10-10-2013** to **10-10-2017**.
- Annual progress reports on the project must be submitted to the Ethics Office.
- If you are a Higher Degree by Research student, data collection must not begin before your Application for Candidacy is approved by your Faculty Graduate Studies Committee.

- The following standard statement **must be** included in the information sheet to participants:
  This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HR 155/2013). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au.

Applicants should note the following:

It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.

The attached **Progress Report** should be completed and returned to the Secretary, HREC, C/- Office of Research & Development annually.

Our website https://research.curtin.edu.au/guides/ethics/non_low_risk_hrec_forms.cfm contains all other relevant forms including:

- Completion Report (to be completed when a project has ceased)
- Amendment Request (to be completed at any time changes/amendments occur)
- Adverse Event Notification Form (If a serious or unexpected adverse event occurs)

Yours sincerely

Professor Stephan Millett
Chair Human Research Ethics Committee

Curtin University Human Research Ethics Committee Reciprocal approval for the SMILE FFQ validation study.

Curtin University

Memorandum

To	Gemma Devenish
From	Wendy Jacobs
Subject	Protocol Approval **SPH-39-2014**
Date	19/06/2014
Copy	Jane Scott

Office of Research and Development
School of Public Health
Human Research Ethics Committee

Telephone 9266 4346
Facsimile 9266 2958
Email w.jacobs@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Low Risk (Ethical Requirements)" for the project titled *"Validation of a food frequency questionnaire to assess the dietary intake of toddlers"*. On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of 4 years – 17/06/2014 to 17/06/2018.

Your approval has the following conditions:

(i) **Annual progress reports on the project must be submitted to the Ethics Office.**

(ii) **It is your responsibility, as the Researcher, to meet the conditions outlined overleaf and to retain the necessary records demonstrating that these have been completed.**

The approval number for your project is **SPH-39-2014.** Please quote this number in any future correspondence. If at any time during the approval term changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

Kind regards

W Jacobs

Wendy Jacobs
Administrative Officer, Research Support
School of Public Health
Curtin University

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk Studies. This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.21).
For further information on this study contact the researchers named above or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

Appendix C SMILE QUESTIONS USED IN THIS RESEARCH

The following questions were used to obtain participant data used within this thesis. The questions are extracted from the SMILE questionnaire booklets administered at recruitment (baseline) and when the child was 3, 6, 12 and 24 months of age.

Socio demographic characteristics

Variable	**Question text**	**Study phase[a]**
Child's birthweight	Please provide the following details of your newborn baby *(please look for the details in your child's Blue book)* Birth Weight_[text entry]_ (kg / lbs) *(please circle)* Birth Length_[text entry]_ (cm / inches) *(please circle)* Head Circumference_[text entry]_ (cm / inches) *(please circle)*	0 months
Child's sex	What is your baby's sex? □1 Male □2 Female	0 months
Mother's age at child's birth	What is your age? _[text entry]_ Years Old	0 months
Mother's pre-pregnancy Body Mass Index	Please provide the following details of yourself How tall are you without shoes? _[text entry]_ (cm / inches) *(please circle)* How much did you weigh at the start of your pregnancy? _[text entry]_ (kg / lbs) *(please circle)* How much did you weigh at the end your pregnancy? _[text entry]_ (kg / lbs) *(please circle)*	0 months
Mother's smoking status at 12 months	Do you currently smoke cigarettes? Yes □1 No □2	12 months
Mother's Education	What is the highest level of education you have? *(one box only)* □1 Some high school □2 Completed high school □3 Some vocational training (i.e. trade) □4 Completed vocational training □5 Some University or College □6 Completed University or College □7 Postgraduate	0 months
Mother's Country of Birth	In which country were you born? □1 Australia □2 Other country *(please specify)* _[text entry]_	0 months
Total number of children	How many OTHER children do you have at home? (Do not count your new baby) _[text entry]_ children	0 months

Household Income	Which category does your total household income (before tax) fall into? Include any salaries, pensions, allowances, benefits, etc from all persons in the household. *(Please tick one box only)* Household income per year: ☐1 Up to $20,000 ☐6 $100,001 to $120,000 ☐2 $20,001 to $40,000 ☐7 $120,001 to $140,000 ☐3 $40,001 to $60,000 ☐8 $140,001 to $160,000 ☐4 $60,001 to $80,000 ☐9 $160,001 to $180,000 ☐5 $80,001 to $100,000 ☐10 Over $180,000	0 months
IRSAD[b]	Postcode _[text entry]_	0 months

[a] Phase of study that provided the data used in these analyses, based on age of child at time of questionnaire administration. Note, if data were missing from baseline questionnaire, but provided at a later date, these were included as if baseline data.
[b] Index of Relative Socio-economic Advantage and Disadvantage

Breastfeeding characteristics: duration of any breastfeeding

Excerpt from 3-month questionnaire (questions repeated at 6, 12 and 24 months*)

A1. How are you feeding your child now?

Breastfeeding only	☐1 → *(Please go to A4)*
Mainly breastfeeding but 'topping up' with bottle-feeding	☐2 → *(Please go to A5)*
Mainly bottle-feeding (infant formula) but also breastfeeding	☐3 → *(Please go to A5)*
Bottle-feeding with infant formula	☐4 → *(Please go to A2)*
Other (please specify) :________________________________	☐5 → *(Please go to A2)*

A2. Has your child ever had breast milk?

Yes ☐1 No ☐2 → *(Please go to A5)*

A3. If you have stopped breastfeeding, how old was your child when he/she stopped receiving any breast milk?
(*Please record your infant's age in completed weeks, e.g. if your child was 9 weeks and 6 days, then record the age as 9 weeks)*

Less than 1 week old ☐1 **OR** ………….weeks → *(Please go to A5)*

***Variation to Question A1 used at 12 and 24 months:**

In addition to solid foods, what types of milk are you giving your child? *(Please tick all that apply.)*

Breast milk	☐1
Infant formula	☐2
Cow's milk	☐3
Other animal milk (e.g. goat's milk)	☐4
Soy milk	☐5
Other non-animal milk (e.g. almond milk, rice milk)	☐6

Breastfeeding characteristics: sleep feeding

Excerpt from 12-month questionnaire (similar questions at 3, 6, and 24 months)

C16 **If currently breastfeeding, how many times on average during the night would you breastfeed your child?**

………….. times   or   I don't breastfeed at night ☐1

C17 **During the past 2 weeks, how often have you put your child to bed with a bottle?**

Never	☐1 → ***(PLEASE GO TO C19)***
At most bedtimes, including naps	☐2
At most night bedtimes, but not daytime naps	☐3
At most daytime naps, but not night bedtimes	☐4
Only occasionally at bedtimes, including naps	☐5

C18 **What is usually in the bottle?**

Infant formula	☐1
Expressed breast milk	☐2
Cow's milk	☐3
Other milk	☐4
Fruit juice/juice drinks	☐5
Water	☐6
Other (please specify)	☐7

……………………………………………….....

Breastfeeding characteristics: other

Excerpt from 3-month questionnaire (questions repeated at 6, 12 and 24 months*)

A4. Has your child ever had any infant formula products?

Yes ☐1   No ☐2 →*(Please go to A8)*

A5. How old was your child when he/she first had an infant formula product?
(Please record your infant's age in completed weeks)

Less than 1 week old ☐1   **OR**   …………..weeks

A6. What type of water do you usually add to the infant formula?

Unfiltered tap/ mains water	☐1
Filtered tap/ mains water	☐2
Tank water	☐3
Bottled water	☐4
Use a premixed formula	☐5

A7. Which infant formula do you usually give your baby?
(*Please give the exact name e.g. S-26 Gold, Heinz Nurture Original)*

____

A8. Has your child received expressed breast milk?

Yes ☐1   No ☐2 *(If not currently breastfeeding →please go to A11)*

A13. Has your child ever drunk water?
(Note: include sips of water, but exclude water combined with solids, powdered milk or infant formula)

No ☐1 → *(Please go to A16)*
Yes, occasionally ☐2
Yes, regularly ☐3

A14. How old was your child when he/she first drank water?
(Please record your infant's age in completed weeks)

Less than 1 week old ☐1 **OR** …………..weeks

A15. What type of water does your baby usually drink?

Unfiltered tap/ mains water ☐1
Filtered tap/ mains water ☐2
Tank water ☐3
Bottled water ☐4

A16. Has your child ever drunk cow's milk?
(Note: include sips of cow's milk, flavoured cow's milk and powdered cow's milk, but exclude cow's milk combined with solid food such as cereal)

No ☐1 → *(Please go to A18)*
Yes, occasionally ☐2
Yes, regularly ☐3

A17. How old was your child when he/she first drank cow's milk?
(Please record your infant's age in completed weeks)

Less than 1 week old ☐1 **OR** …………..weeks

A18. Has your child ever drunk other milks (e.g. soy milk, rice milk, goat milk)**?**
(*Note: Include sips of other milks, but exclude other milks combined with solid food)*

No ☐1 → *(Please go to A20)*
Yes, occasionally ☐2
Yes, regularly ☐3
If yes, please specify the type of milk

____

A19. How old was your child when he/she first drank other milk?
(Please record your infant's age in completed weeks)

Less than 1 week old ☐1 **OR** …………..weeks

A20. Has your child ever drunk fruit juice?
(Note: Include sips of fruit juice and diluted fruit juice, but exclude fruit juice combined with solid food)

No ☐1 → *(Please go to A22)*
Yes, occasionally ☐2
Yes, regularly ☐3

A21. How old was your child when he/she first drank fruit juice?
(Please record your infant's age in completed weeks)

Less than 1 week old ☐1 **OR** …………..weeks

A22. Has your child ever drunk sweetened drinks (e.g. cordial, soft drinks)**?**

No ☐1 → *(Please go to A24)*
Yes, occasionally ☐2
Yes, regularly ☐3

A23. How old was your child when he/she first drank sweetened drinks?
(Please record your infant's age in completed weeks)

Less than 1 week old ☐1 **OR** …………..weeks

Appendix D SMILE-FFQ

SMILE Food Frequency Questionnaire

INSTRUCTIONS

This questionnaire asks you to describe your child's usual intake of food. Please read and follow these instructions carefully.

This questionnaire:

- is designed to find out what your child ***usually*** eats and drinks, but only for certain food types. It does not ask about every food your child eats.
- looks at current, usual eating habits of your child. We are interested in foods and drinks that are consumed regularly (i.e. more than once per week).
- is meant to collect information about each food ONCE only. Occasionally you may find that some foods could fit into two categories – but please include it in just one.

How to fill in this section

This section asks **how often** your child eats certain foods, and **how much** they eat when they do.

Watch out – the amounts change!

For example, if your child eats plain dried fruit 5 days per week, and when they do they usually eat about 1 tablespoon, fill in the table like this:

Please answer EITHER: This: OR Both of these

This:		In a typical week, how often would your child eat the item:							When they eat it, how much would your child usually eat?				
My Child Never or Rarely eats this (1)	OR	1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	4-8 sultanas, 2 dates or dried apricot halves (10g) (1)	1 Tablespoon, 3-4 dates or dried apricot halves (20g) (2)	2 Tablespoons or a snack box (40g) (3)	1/2 cup or 2 snack boxes (80g) (4)	More than 1/2 cup (100g+) (5)

Dried Fruit: Plain (2)
e.g. sultanas, dried mango, apricot etc. Do NOT include fruit bars or fruit leather

○	OR	○	○	○	✓	○	○	&	○	✓	○	○	○

And, if your child doesn't eat coated dried fruit, or only very occasionally, fill it in like this:

Please answer EITHER: This: OR Both of these

This:		In a typical week, how often would your child eat the item:							When they eat it, how much would your child usually eat?				
My Child Never or Rarely eats this (1)	OR	1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	4-8 sultanas, 2 dates or dried apricot halves (10g) (1)	1 Tablespoon, 3-4 dates or dried apricot halves (20g) (2)	2 Tablespoons or a snack box (40g) (3)	1/2 cup or 2 snack boxes (80g) (4)	More than 1/2 cup (100g+) (5)

Dried Fruit: Coated (1)
in chocolate, carob, yoghurt etc

✓	OR	○	○	○	○	○	○	&	○	○	○	○	○

Please note

Please provide your answers for a typical week – rather than what your child ate in the last 7 days, think about their usual intake. Where possible, **include foods your child eats while in the care of others**, for example at childcare or with relatives. Although some toddlers are messy or fussy eaters, **please try to answer based on how much your child actually eats**, rather than what is served to them.

Please try to answer as accurately and honestly as possible. There are no right or wrong answers. You may find it easier to complete this section when you have time to look at foods inside your fridge or pantry!

Milk and Milk Alternatives

In this section:

Milk refers to any animal milk (cow, sheep, goat) in any form (fresh, powdered, long-life etc)

Milk Alternatives refer to any plant based milks (soy, rice, oat, almond etc)

Please answer EITHER:

This: | **OR Both of these**

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? A few sips (less than 50ml) (1)	125mL: Half a cup or baby bottle (2)	200mL: A small cup (eg sippee) or baby bottle (3)	250mL: A medium cup or baby bottle (4)	350mL: A large cup or baby bottle (5)	450mL: A very large cup or baby bottle (6)	600mL: A carton or soft-drink sized bottle (7)
Flavoured Milk (1) — Includes choc-milk, strawberry milk etc, plus milkshakes and other café milk drinks. Do NOT include plain milk that you add flavour to															
○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○
Regular Milk (plain, unflavoured) (2) — Include ALL plain milk consumed, including milk given as a drink (with or without additions), added in cooking or when served															
○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○
Flavoured Milk Alternatives (3) — Includes soy and other alternative milk products purchased flavoured with chocolate, strawberry etc, plus milkshakes and other café items ordered with milk alternatives															
○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○
Regular Milk Alternatives (plain, unflavoured) (4) — Include ALL plain milk alternatives consumed, including milk given as a drink, added in cooking or when served															
○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○
Infant Formula and Toddler Milk (all types) (5) — Include ALL formulations for infants or toddlers, including regular step 1-4 powders, regular and special formulations, made from milk or milk alternatives.															
○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Condensed and Evaporated Milk

Please answer EITHER: This: OR Both of these

	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 1 teaspoons (5mL) (1)	2 teaspoons (10mL) (2)	3 teaspoons (15mL) (3)	1 Tablespoons (20mL) (4)	2 Tablespoons (40mL) (5)	3 Tablespoons (60mL) (6)	1/4 Tin (100mL) (7)	1/2 Tin (200mL) (8)	3/4 Tin (300mL) (9)	1 or more tins (400mL+) (10)
Condensed Milk (1)	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Evaporated Milk (2)	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Cheese

Please answer EITHER: This: OR Both of these

	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 1 small square or smear (enough for 1 cracker) (1)	20g: 1 single serve portion, slice or 2 (1cm) cubes (2)	40g: 2 slices or 4 (1cm) cubes (3)	70g: 3-4 slices or half a cup, grated (4)	100g: 5 slices or 3/4 of a cup, grated (5)	120g: 6 slices or 1 cup, grated (6)	150g+: More than 6 slices (7)
Cream Cheese or Ricotta (1) Include individually wrapped cream cheese such as Laughing Cow	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍
Other Soft Cheeses (2) Including feta, brie etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍
Hard Cheese (3) Include cheddar, tasty, mozzarella, grated cheese blends, cheese sticks, single wrapped slices etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍
Cheese Alternatives: Any Type (4) Include any kind of hard or soft cheese alternative, Notzarella, Tofutti, soy cheese etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍

Yoghurt

Please answer EITHER:

This: | OR Both of these

	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 3 teaspoons (20mL or less) (1)	2-3 Tablespoons, a small pouch (60mL) (2)	Less than 1/2 cup, or 1 junior tub or regular pouch (100mL) (3)	More than 1/2 cup, or a medium tub (150mL) (4)	2/3 cup, a regular tub (adult tub) (200mL) (5)	1 cup, more than a regular tub (250mL+) (6)
Children's Yoghurt (1) Anything with a cartoon character on the package, &/or yoghurt sold in a mini tub, pouch, stick etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Plain or Natural Yoghurt (2) Anything that is not flavoured	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Fruit Flavoured Yoghurt (3) e.g. strawberry, banana, fruits of the forest, coconut, apricot etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Any Other Flavoured Yoghurt (4) e.g. vanilla, honey, French cheesecake etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Probiotic Yoghurt Drinks (5) e.g. Yakult, Vaalia Innergy, Coles Pro-B etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Yoghurt Alternatives: Flavoured (6) Yoghurt made from soy, coconut or other plant-based milk alternatives; include fruit flavours and dessert styles, such as mixed berry, mango, vanilla etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Yoghurt Alternatives: Plain (7) Yoghurt made from soy, coconut or other plant-based milk alternatives; include any plain, natural or unflavoured types	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍

If your child eats yoghurt, do you choose reduced fat versions?

- ❍ Usually (1)
- ❍ Sometimes (2)
- ❍ Never or Rarely (3)
- ❍ I don't know or my child does not eat yoghurt (4)

Cream and Custard

Please answer EITHER: This: OR Both of these

	This:		In a typical week, how often would your child eat the item:							When they eat it, how much would your child usually eat?				
	My Child Never or Rarely eats this (1)	OR	1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	3 teaspoons (20mL or less) (1)	2-3 Tablespoons, a small pouch (60mL) (2)	1/2 cup, a junior tub or regular pouch (125mL) (3)	2/3 cup (200mL) (4)	1 cup or more (250mL+) (5)
Cream or Sour Cream (1) Unsweetened varieties only	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍
Infant and Toddler Custard: Plain or Vanilla Only (2) Usually found in the baby aisle, or in single-serve pouches in the fridge section	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍
Regular Custard: Plain or Vanilla Only (3) Include store-bought or home-made custards	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍
All Other Kinds of Flavoured Custard and Custard-like Desserts (4) e.g. YoGo, SnakPack, any chocolate or banana custard, sweetened or sweet-flavoured cream, chocolate mousse, baked custard etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍
Other milk-based desserts (not frozen) (5) Such as rice pudding (store-bought or home-made)	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍

Frozen Desserts

In this section: Consider those purchased at the supermarket, as well as from a deli, petrol station, ice cream shop, drive-thru, grandma's house etc

Please answer EITHER: This: OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?				
		1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)		3 teaspoons (20g or less) (1)	1 small scoop or mini-pop (around 40g) (2)	1 medium scoop or medium serve on a stick eg a Choc Wedge (80g) (3)	2 medium scoops or a large serve on a stick eg a Magnum (125g) (4)	3 scoops or more (175g+) (5)

Ice cream and frozen yoghurt (1)
Includes any frozen, milk-based dessert or treat, in a tub, on a stick, bought by the scoop etc

○	OR	○	○	○	○	○	○	&	○	○	○	○	○

Icy Poles and Sorbet (2)
Includes any other frozen desserts and treats that are like ice cream, but NOT made from milk or milk alternatives

○	OR	○	○	○	○	○	○	&	○	○	○	○	○

Ice Cream Alternatives and Other Frozen Milk Alternatives (3)
Includes any dairy free, milk-style frozen desserts such as soy ice cream in a tub or on a stick, frozen soy or coconut yoghurt, Tofutti Cuties etc

○	OR	○	○	○	○	○	○	&	○	○	○	○	○

Fruit

Please answer EITHER: This: OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?			
		1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)		30g: eg 1/2 a plum, mandarin or kiwi, 1 small apricot, or 4 grapes or large berries (1)	70g: eg 1 small piece (plum, kiwi etc), 6-8 grapes or large berries, 1/2 a medium piece (apple, banana, orange etc) (2,3)	150g: eg 1 medium piece (apple, banana, pear, orange), 2 small pieces, or 1 cup of grapes or berries (4)	175g+: More than 1 medium piece or 2 small pieces (5)

Fresh or Frozen Fruit: All Types (1)
e.g. banana, apple, watermelon, grapes, pear, berries etc

○	OR	○	○	○	○	○	○	&	○	○	○	○

Dried Fruit

Please answer EITHER: This: OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 4-8 sultanas, 2 dates or dried apricot halves (10g) (1)	1 Tablespoon, 3-4 dates or dried apricot halves (20g) (2)	2 Tablespoons or a snack box (40g) (3)	1/2 cup or 2 snack boxes (80g) (4)	More than 1/2 cup (100g+) (5)
Dried Fruit: Coated (1) in chocolate, carob, yoghurt etc													
O	OR	O	O	O	O	O	O	&	O	O	O	O	O
Dried Fruit: Plain (2) e.g. sultana, dried mango, apricot etc. Do NOT include fruit bars or fruit leather													
O	OR	O	O	O	O	O	O	&	O	O	O	O	O

Tinned Fruit

Please answer EITHER: This: OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 20g: eg 1 peach slice or apricot half (1)	40g: eg 2 apricot halves or 1 pineapple ring (2)	80g: eg 4 peach slices, 4 apricot halves, 1 pear half (3)	120g: eg 1/2 cup or 1 snack tub (4)	160g: eg 8 peach slices, 2 pear halves (5)	200g: eg 3/4 cup, 1/2 a regular tin (6)	240g: eg 1 cup, 3 pear halves (7)
Tinned Fruit: Whole or Pieces (1) not puree															
O	OR	O	O	O	O	O	O	&	O	O	O	O	O	O	O

If your child eats tinned fruit, which do you usually choose?

- O Fruit in syrup (1)
- O Fruit in natural juice (2)
- O Both types equally (3)
- O I don't know or my child does not eat tinned fruit (4)

If your child eats tinned fruit, do they eat or drink the syrup or juice?

- O Usually (1)
- O Sometimes (2)
- O Never or Rarely (3)
- O I don't know or my child does not eat tinned fruit (4)

Pureed Fruit and Vegetables

Please answer EITHER:

This: | OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 2 teaspoons (15g or less) (1)	1-2 Tablespoons (35g) (2)	3 Tablespoons or 1/2 a pouch or baby jar (65g) (3)	1/2 cup or 1 pouch or baby jar (120g) (4)	3/4 cup, 1.5 pouches (200g) (5)	1 cup, 2 pouches or baby jars or more (250g+) (6)
Toddler or Infant Fruit Puree (1) Usually found in the baby aisle: sold in jars, pouches, tins etc														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Toddler or Infant Vegetable Puree (2) Usually found in the baby aisle: sold in jars, pouches, tins etc.														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Fruit Puree: Other, Shop Bought (3) Not from the baby aisle														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Fruit Puree: Home-Made (4)														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍

Nuts

Please answer EITHER: This: OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?					
		1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	5 nuts or less (5-10g) (1)	10 nuts or less (15-25g) (2)	1-2 Tablespoons, 15-20 small nuts (3)	1/4 cup (35-50g) (4)	1/2 cup (75-100g) (5)	3/4 cup or more (120g+) (6)
Nuts: Coated (1) in chocolate, carob, yoghurt, honey etc														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Nuts: All Other Types (2) Include roasted or raw, whole or chopped, salted or spiced etc, Do NOT include nut pastes														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍

Nut Pastes and Other Spreads

Please answer EITHER: This: OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?							
		1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	1/2 (1) teaspoons	1 (2) teaspoons	2 (3) teaspoons	3 (4) teaspoons	1 (5) Tablespoons	2 (6) Tablespoons	3 (7) Tablespoons	4 or more (8) Tablespoons
Nut Paste (1) Include peanut butter, almond spread, cashew paste etc. Do NOT include chocolate flavoured																
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Chocolate or Carob Spread (2) With or without nuts e.g. Nutella, Kraft Hazelnut spread, Sweet William Chocolate etc																
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Jam, Marmalade and Other Fruit Spreads (3) Store-bought or home-made																
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Honey (4)																
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍

Breakfast Cereal

Please answer EITHER: This: OR Both of these

Item	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? A small sprinkle, 1-2 Tablespoons or 1/2 a wheat biscuit (1)	1/4 cup (30g muesli, 15g flakes) or 1 wheat biscuit (2)	1/2 cup (60g muesli, 25g flakes) or 2 wheat biscuits (3)	1 cup (120g muesli, 50g flakes) or 3 wheat biscuits (4)	More than 1 cup, 4 or more wheat biscuits (5)
Porridge or Other Hot Cereal (1)	○	OR	○	○	○	○	○	○	&	○	○	○	○	○
Wheat Biscuits: Plain (2) e.g. Weet-Bix, Vita Brits etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○
Puffed, Unflavoured Cereal (3) e.g. puffed corn, puffed rice	○	OR	○	○	○	○	○	○	&	○	○	○	○	○
Muesli: Toasted (4)	○	OR	○	○	○	○	○	○	&	○	○	○	○	○
Muesli: Untoasted (5)	○	OR	○	○	○	○	○	○	&	○	○	○	○	○
Cereal Flakes (6) e.g. Cornflakes, Weeties, Sultana Bran, Light n Tasty etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○
Flavoured Breakfast Cereal: All Other Types (7) e.g. Coco-Pops, Honey Puffs, Cheerios, Nutri-Grain, MiLo, Mini-Wheats, Weet-Bix Bites etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○

Biscuits

In this section: Include both **home-made and commercial** varieties

Please answer EITHER:

This: | OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 1-2 bites or mini-biscuits, or 1 mini meringue (1)	1/2 a medium biscuit or 4 mini-biscuits (2)	1 medium biscuit or meringue (3)	2 medium biscuits, or 1 snack pack (4)	3 medium biscuits (5)	4 or more medium biscuits (6)

Plain, Sweet Biscuits and Wafers (1)

e.g. Milk Arrowroot, Tiny Teddy, Tina Wafer, Scotch Finger (uncoated), Wheatmeal, Animal Biscuit, Vanilla bite, Shortbread etc. Include shop-bought and home-made.

❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍

All Other Sweet Biscuits and Cookies (2)

Include filled or coated varieties e.g. Choc-chip, Tim-Tam, Tic-Toc, Monte Carlo, Jam Drop, Melting Moment, Full-o-Fruit etc. Include shop-bought and home-made.

❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍

Meringue or Honeycomb (3)

❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍

Bars and Bar-Like Snack Food

In this section: Include both home-made and commercial varieties

Please answer EITHER:

This: | OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 15g: eg 1/2 a medium bar, 1 Roll-Up (1)	20g: eg 1 fruit stick, 1 small crackle, 1 LCM (2)	30g: eg 1 medium bar, 2 roll ups (3)	40g: eg 2 fruit sticks, 1 large or 2 small crackles (4)	50g: eg 1 large bar, 3 small crackles (5)	60g: eg 2 medium bars (6)	100g: eg 1 extra large bar (7)

Honey Joys, Chocolate Crackles and Puffed Cereal Bars (1)
e.g. LCM Nutri-Grain bar, Milo bar, honey crackle etc

○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Cake or Muffin Bars and Muesli Bars (2)
e.g. Yoghurt tops, K-Time twist, breakfast bar, chewy/crunchy muesli bar, trail bar, nut bar, oat bar etc

○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Fruit Flavoured Snacks (3)
includes fruit sticks, straps, balls, squares, bars, leather, Roll-Ups etc

○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Cakes and Puddings

In this section: Include both home-made and commercial varieties

Please answer EITHER:

This: | OR Both of these

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 1/2 a cupcake, 1 medium doughnut or 2 mini muffins (40g) (1)	1 cupcake, large doughnut or small muffin (80g) (2)	1 medium café muffin (120g) (3)	2 cupcakes, 4 doughnuts or a large café muffin (160g) (4)

Cakes, Muffins, Slices, Doughnuts and Puddings (1)
Includes brownies, cup-cakes, iced or plain doughnuts, cakes and cake-based desserts such as self-saucing pudding, fruit cake, bread pudding, lemon delicious etc

○	OR	○	○	○	○	○	○	&	○	○	○	○

Sweet Bread and Pastry

In this section: Include both home-made and commercial varieties

Please answer EITHER: This: OR Both of these

Item	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 1/2 a pancake or 1 large pikelet (40g) (1)	1/2 a medium croissant or finger bun, or 1 slice of fruit bread (50g) (2, 3)	1 pancake, 2-3 pikelets (80g) (4)	1 medium croissant or finger bun, or 2 slices of fruit bread (100g) (5, 6)	2 pancakes, or 4-6 pikelets (160g) (7)	More than 3 pancakes or 8 pikelets (200g+) (8)
Sweet Bread and Pancakes (1) Includes finger bun, fruit bread, cinnamon scroll, pikelet, scone, waffle etc.	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○
Sweet Pastry (2) Includes croissant, strudel, Danish pastry, baklava etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○

Savoury Snack Food

Please answer EITHER: This: OR Both of these

Item	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? 10g: eg 6 rice crackers or Shapes, 2 Jatz, 1 Sao or Corn Thin (1)	15g: eg 2 Cruskits or 1 thick rice cake (2)	25g: eg 1 snack pack, 10 crisps or corn chips, 1 'row' of rice crackers (3)	40g: eg 4 corn thins, 5 Cheds, 8 Jatz (4)	50g: eg 2 rows of rice crackers, 5 Sao, 1/4 of a large packet of Chips or box of Shapes etc (5, 6)	100g: eg 1/2 a large packet of crisps, or box of shapes etc or 1 packet of rice crackers (7)	120g+: more than 1/2 a large packet or box (8)	150g+: More than 6 slices (8)
Plain Savoury Biscuits or Crackers (1) e.g. Sao, Jatz, water thins, plain rice crackers, plain corn thins, plain rice cakes, plain breadsticks etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Flavoured Savoury Biscuits or Crackers (2) e.g. Chedz, Shapes, flavoured rice crackers, flavoured corn cakes or rice thins etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Savoury Snack Foods (3) Includes potato crisps, corn chips, prawn crackers, Rice Wheels, Mamee noodle snack, Cheese Fiddlesticks etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○

Drinks

In this section: Some of these may be difficult to answer if your child sips throughout the day. If that is the case, try to get the total amount correct.

For example, if your child had 200ml of juice in sips over the whole day, you could report 50ml three or more times a day, or 125ml one to two times per day.

Please answer EITHER: **This:** **OR Both of these**

Item	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? A few sips (50ml or less) (1)	125mL: Half a cup or baby bottle or 1 mini juice box (2)	200mL: A small cup (eg sippee), baby bottle or mini can (3)	250mL: A medium cup, baby bottle or regular juice box (4)	350mL: A large cup or regular can (5)	450mL: A very large cup or medium drink bottle (6)	600mL: A soft-drink sized bottle (7)	More than 600mL (6)
Water: Plain, Still (1) Tap, bottled etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Water: Plain, Carbonated (2) e.g. soda water, sparkling water etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Water: Lightly Flavoured, Clear (3) Although there is some flavour, these water-based drinks are still clear, e.g. PumP water with a twist, PLaY fruit water, coconut water etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Junior Juice (4) Infant or toddler juice, usually found in the baby aisle	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
All Other Fruit Juice or Fruit Juice Drinks (5) Including poppers, juice boxes and bottled juice sold refrigerated or at room temperature, purchased in a café, home squeezed etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Vegetable Juice (6) Include store bought or home-made	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○

Continued over

Drinks *continued*

Please answer EITHER: This: OR Both of these

	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? A few sips (50ml or less) (1)	125mL: Half a cup or baby bottle or 1 mini juice box (2)	200mL: A small cup (eg sippee), baby bottle or mini can (3)	250mL: A medium cup, baby bottle or regular juice box (4)	350mL: A large cup or regular can (5)	450mL: A very large cup or medium drink bottle (6)	600mL: A soft-drink sized bottle (7)	More than 600mL (8)
Cordial: Diet, Lite or Sugarfree (7)	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Cordial: All Other Types (8)	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Soft Drink: Diet, Lite or Sugarfree (9)	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Soft Drink: All Other Types (10) Include cola, fruit flavours, energy drinks, red creaming soda, lemonade etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Frozen Drinks (11) e.g. slushy, granita, Frozen Coke etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Tea: From Leaves (12) Any types from loose leaf or tea bag, including black, white, green, herbal, tisane, chai leaf etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○
Tea: From Powder, Syrup or Pre-made (13) e.g. chai powder or syrup, Lipton iced tea etc	○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○	○

If your child drinks juice, do you look for products with "no added sugar" or "100% fruit juice" on the label?

- ❍ Usually (1)
- ❍ Sometimes (2)
- ❍ Never or Rarely (3)
- ❍ I don't know or my child does not drink juice (4)

Drink Powder

Please answer EITHER: This: OR Both of these

	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item: 1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	When they eat it, how much would your child usually eat? teaspoons: 1/2 (1)	teaspoons: 1 (2)	teaspoons: 2 (3)	teaspoons: 3 (4)	Tablespoons: 1 (5)	Tablespoons: 2 (6)	Tablespoons: 3 (7)	Tablespoons: 4 or more (8)
Drink Powder: Added Vitamins and Minerals (1) e.g. Milo, Ovaltine, Sustagen etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Drink Powder: Regular (2) e.g. drinking chocolate, Nesquik (any flavour), Sipahh straws etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍

What does your child usually drink from?

	My child rarely or never uses this(1)	My child sometimes uses this(2)	My child regularly or always uses this(3)
A regular cup or glass without a straw(1)	❍	❍	❍
A regular cup or glass with a straw(2)	❍	❍	❍
A sipper cup(3)	❍	❍	❍
A bottle with a teat(4)	❍	❍	❍
A sports or drink bottle with straw, pop-top etc(5)	❍	❍	❍
Other, please give details(6):	❍	❍	❍

Sauces and Condiments

Please answer EITHER:

This: | OR Both of these

	My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?							
			1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	teaspoons 1/2 (1)	teaspoons 1 (2)	teaspoons 2 (3)	teaspoons 3 (4)	Tablespoons 1 (5)	Tablespoons 2 (6)	Tablespoons 3 (7)	Tablespoons 4 or more (8)
Tomato or Barbecue Sauce (1) Also known as ketchup	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Sweet Marinades and Sauces (2) Such as oyster sauce, kecap manis, sweet chilli, hoisin, plum sauce etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Mayonnaise: Low Fat (3) Include all reduced fat types e.g. traditional, egg mayo, aioli etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Mayonnaise: Not Low Fat (4) Include all regular fat types e.g. traditional, egg mayo, aioli etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Chutney or Relish (5) e.g. mango chutney, corn relish, tomato chutney, onion relish etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Dessert Toppings (6) e.g. chocolate, caramel, butterscotch, strawberry sauces, Ice Magic etc	❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍

Sugar and Sugar Substitutes

In this section: Include sugar added in cooking or serving, sprinkled on cereal, stirred into a drink etc. Do NOT include sugar used to bake cakes or biscuits.

Please answer EITHER: **This:** **OR Both of these**

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?							
		1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)		1/2 (1) teaspoons	1 (2) teaspoons	2 (3) teaspoons	3 (4) teaspoons	1 (5) Tablespoons	2 (6) Tablespoons	3 (7) Tablespoons	4 or more (8) Tablespoons
Sugar: Solid or Granulated (1) Include regular table sugar, white, brown, raw, palm and date sugar																
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Sugar: Syrups Other Than Honey (2) Such as agave, maple, golden syrup, corn or rice syrup																
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍
Sweeteners: No or Low Calorie (3) e.g. Equal, Splenda, Stevia, Nutrasweet etc																
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍	❍	❍

Jelly

Please answer EITHER: **This:** **OR Both of these**

My Child Never or Rarely eats this (1)	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?					
		1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)		2 teaspoons (10mL) (1)	2 Tablespoons (40mL) (2)	1/4 of a cup (60mL) (3)	1/2 a cup (125mL) (4)	1 cup (250mL) (5)	More than 1 cup (6)
Jelly: Diet, Lite or Sugarfree (1) Do NOT include "natural" or "25% less sugar" jelly in this group *Note: 1 standard box of jelly crystals makes 2 cups (500ml) of jelly*														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍
Jelly: Regular (2) Include all other types, such as natural, 25% less sugar, agar jelly, fruit flavours, make-your-own flavour etc														
❍	OR	❍	❍	❍	❍	❍	❍	&	❍	❍	❍	❍	❍	❍

Chocolate and Lollies

Note: lollies are also known as candy or sweets

Please answer EITHER: This: OR Both of these

This:	OR	In a typical week, how often would your child eat the item:						&	When they eat it, how much would your child usually eat?						
My Child Never or Rarely eats this (1)	OR	1 time every 2 weeks (2)	1 time per week (3)	2-3 times per week (4)	4-6 times per week (5)	1-2 times per day (6)	3 or more times per day (7)	&	10g: eg 2 soft or hard lollies, 2 squares of chocolate, 1 Redskin or lollipop, 2 marshmallows (1,2)	20g: eg 1 fun-size bar, 4 lollies (3)	25g: eg 5 lollies or marshmallows, 1 row of chocolate (4)	40g: eg 2 fun-size bars, 8 lollies (5)	50g: eg 10 lollies or marshmallows, 2 rows of chocolate, 1 regular chocolate bar, 1/3 of a bag of lollies (6,7)	75g: eg 1 large chocolate bar (king size), 1/2 a bag of lollies (8)	100g or more (9)

Chocolate or Carob: All Types (1)
Include solid or filled chocolate, chocolate bars, blocks, buttons, M&Ms etc

○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Lollies: Sugarfree (2)
Do NOT include "natural" or "no added sugar" lollies

○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Lollies That Last a Long Time (3)
Any that take a long time to eat: either because they are sticky and stay in the mouth (e.g. Minties, Red Skins) or because they are hard and have to be sucked, (e.g. lollipops, gobstoppers, toffees etc)

○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Lollies: All Other Types (4)
Include anything not already included, such as soft and gummy lollies, liquorice, marshmallow, Skittles, sour worms, party mix etc including "natural" and fruit types

○	OR	○	○	○	○	○	○	&	○	○	○	○	○	○	○

Think about a typical day of eating for your child. On a typical day, how many meals, drinks other than water and snacks does your child eat ?

A meal is generally larger and made of a mixture of different foods. A snack is generally smaller, eaten more quickly and made of only one or two different foods. *Note that some foods may be thought of as a meal OR a snack depending on the time of day and amount eaten. For example, 1 peanut butter sandwich at lunchtime is a meal, half a sandwich in the car at 10am is a snack.*

On a typical day my child has:

☐ meals per day(1)
☐ between meal snacks per day(2)
☐ drinks other than water per day: with food(3)
☐ drinks other than water per day: without food(4)

Appendix E 24-HOUR RECALL PROBING PROTOCOL

This protocol was used in SMILE to conduct the 12 month dietary data, and in the SMILE-FFQ Validation Study. It is in two parts; consisting of a phone interview script, and a set of probing prompts for use in the detail cycle.

Contents

Part One: Phone Protocol (Interview Script)

A. Commencement - Use your own, more specific script for this section

Phone Participant

↓

- *1. Voicemail* → Hello <Participant Name>, this is <name> from the <study name>. I will try to call a bit later today. If you would like to contact me, my number is <number>, but I will give you a call soon. Thanks. → Call again later
- *2. Someone else answers (or unknown)* → Hello, this is <name> from the <study name>, I am calling for <participant name> is (s)he available?
  ↓
  - *1. No* → No problem, I can call back later today, do you know if there is a time that would be convenient to call?
    ↓
    - *1. No* → That's fine, I'll just try again later, thanks for your help (END CALL)
    - *2. Yes* → Arrange a time to call later that day (END CALL)
    - *3. Today is no good* → That's fine, I'll just try again another day, thanks for your help (END CALL)
  - *2. Yes* ↓
- *3. Participant answers* → Hello, this is <name> from the <study name>, how are you <participant name>?

↓

I am calling to conduct a phone survey, is now an ok time to do that? It will probably take 15-20 minutes.

- *1. Yes* → Great, let's get started! → GO TO SECTION B
- *2. Today is no good* → That's fine, are you happy for me to call again another day? (wait for response) Ok, thanks for your help (END CALL)
- *3. No* → No problem, I can call back later. Is there another time today that we could do the survey?
  ↓
  - *1. No* → That's fine, are you happy for me to call again another day? (wait for response) Ok, thanks for your help (END CALL)
  - *2. Yes* → Arrange a time to call later that day (END CALL)

B. Introduction - First time version

I'm going to ask you a series of questions about what <childname> ate yesterday.

↓

Did you receive the booklet that we sent in the mail? Do you have access to that at the moment?

↓

1. No	→	It's okay if you don't have it in front of you. We can c survey without it. Continue without. ↙
2. Yes	↓	

Now I'm going to ask you to tell me about the foods and drinks that *<childname>* had yesterday. This is from midnight of the night before last night, that is midnight *<insert day>* to midnight last night, *<insert day>* .
First we will make a brief list of all meals, snacks, and drinks, including water, as well as small tastes or samplings of foods. Next, I'll ask you for more detail about each item. You can use the pdf of images to help describe how much of each item *<childname>* actually ate. Finally, we'll go through the list one last time to make sure we have everything.
Young children can be messy eaters and often spill foods or drinks on the table or on themselves, and they often leave food on their plate or in their bottle or cup. We're only interested in the amount of food your child actually ate yesterday, so it's important to think about foods and drinks that may have been spilled or leftover when you tell me how much of each item was eaten.

↓

Was *<childname>* in child care or with a baby sitter or someone else part of the day yesterday?

1. No	→	GO TO SECTION C
2. Yes	↓	

What time was <childname> in child care or with a baby sitter or someone else yesterday?

Record time as a range (eg 9-11am or 1130-1345)

↓

Do you know if they had anything to eat or drink during that time?

1. I know they didn't	→	GO TO SECTION C
2. I know they did, but I don't know what it was	→	GO TO SECTION C
3. I know they did, and I do know what it was	→	GO TO SECTION C (If they describe, make a note as p of 24hr recall)
4. I don't know	→	GO TO SECTION C

B. Introduction - Repeat version

Use name from previous phone call. Modify as required if participant was resistant to give name last time.

As I did previously, I'm going to ask you a series of questions about what *<childname>* ate yesterday.

Did you have that booklet that we sent you? Can you access it at the moment?

↓

1. No → It's okay if you don't have it in front of you. We can c survey without it.

2. Yes Continue without.

↓ ↙

Now I'm going to ask you to tell me about the foods and drinks that *<childname>* had yesterday. So from midnight of the night before last, that was *<insert day>* to midnight last night, *<insert day>*.

First we will make the brief list of all meals, snacks, and drinks, including water, as well as small tastes or samplings of foods. Next, I'll ask you for more detail about each item. You can use the pdf of images to help describe how much of each item *<childname>* actually ate. Finally, we'll go through the list one last time to make sure we have everything.

And the same as last time, we are only interested in the amount of food your child actually ate yesterday, so it's important to think about foods and drinks that may have been spilled or leftover when you tell me how much of each item was eaten.

↓

Was *<childname>* in child care or with a baby sitter or someone else part of the day yesterday?

1. No → GO TO SECTION C

2. Yes

↓

What time was <childname> in child care or with a baby sitter or someone else yesterday?

Record time as a range (eg 9-11am or 1130-1345)

↓

Do you know if they had anything to eat or drink during that time?

1. I know they didn't → GO TO SECTION C

2. I know they did, but I don't know what it was → GO TO SECTION C

3. I know they did, and I do know what it was → GO TO SECTION C (If they describe, make a note as p of 24hr recall)

4. I don't know → GO TO SECTION C

C. The Quick List

Now, take a moment to think about the rest of your child's day yesterday, what (s)he did, where (s)he went and so forth. This can help you to remember what and when *<childname>* ate. When you are ready, you can start to list the foods and drinks. If it's easy to do as you go, try to tell me the approximate time *<childname>* ate the foods. For example, "at 6 am (s)he had milk, at 8:30 (s)he had cereal and juice" and so on.

So, after midnight, on [DAY] when was the first time that *<childname>* had something to eat or drink?

↓

Record as per the form. Do not interrupt the participant during this time. Suitable prompts include: "was there anything else?", "yes, keep going", "what else did (s)he eat or drink?", "is that everything?" etc

↓

GO TO SECTION D

D. Forgotten foods

Your answers are important, so we'd like to make this list as complete as possible. I'm going to ask you about some foods that are often forgotten.
In addition to the foods that you have told me about, did <childname> have any other drinks, such as milk, juice, softdrink etc?

1. Yes → Record, then continue
2. No
↓

Did (s)he have any biscuits, lollies, ice cream, chocolate, or other sweets?

2. No ↓ | *1. Yes* → Record, then continue

Did (s)he have any chips, crackers, nuts, or other snack food?

2. No ↓ | *1. Yes* → Record, then continue

Did <childname> have any rusks or teething foods?

2. No ↓ | *1. Yes* → Record, then continue

Any fruit, vegetables or cheese?

2. No ↓ | *1. Yes* → Record, then continue

And any bread or bread rolls?

2. No ↓ | *1. Yes* → Record, then continue

Are there any other foods that have come to mind?

2. No ↓ | *1. Yes* → Record, then continue

GO TO SECTION E

E. Time

Tailor this section to what the participant has already provided:

1) If all times given previously → GO TO SECTION F
2) If some or no times given

↓

About what time did <childname> begin to eat/drink the [food or drink item]

↓

Record as per the form.
If IDK, try for morning/afternoon/evening/overnight

Repeat question until all foods and drinks have a time

When complete: → GO TO SECTION F

F. Detail Cycle

Ok, now I am going to ask you for some more detail about the foods and drinks you have listed. If you think of anything else that you had forgotten, please feel free to interrupt me and we can add it in to the list. It is better to say it when you think of it, rather than wait and risk forgetting.

Tailor this section to the food list.
Step chronologically through the day, and use the additional probing info to drive the probing questions.

Let's start at the beginning, so you said that at <*time*>, <childname> ate/drank <food>...

↓

Record detail as per the form, with reference to the Food Instruction Booklet. For each food item, collect ***DESCRIPTION, AMOUNT*** *and any* ***ADDITIONS***

When complete: → GO TO SECTION G

G. Review and final probe.

We are nearly finished. I am going to read it back to you one last time, and again if there is anything else or something is incorrect feel free to interrupt me as we go.

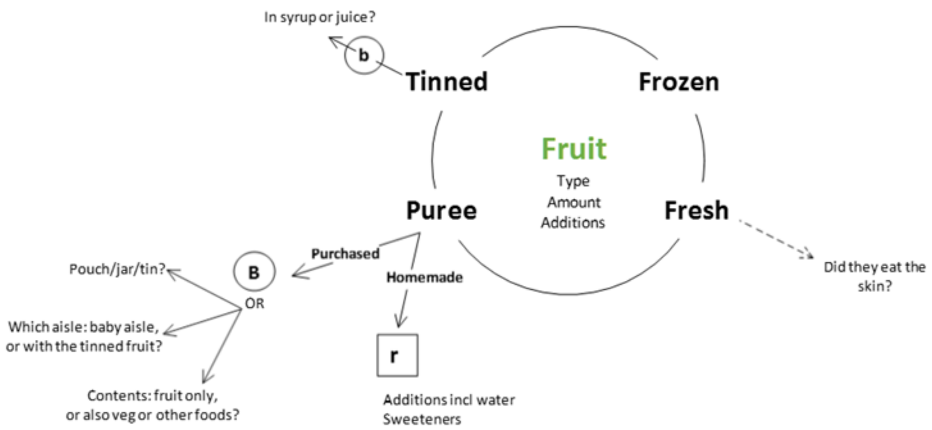
Read it back (ok to skip over some of the detail)

Do you think this is everything?
Would you say that yesterday was a fairly typical day of eating for your child?
(Record: Yes, More or less than usual, or note other comment)

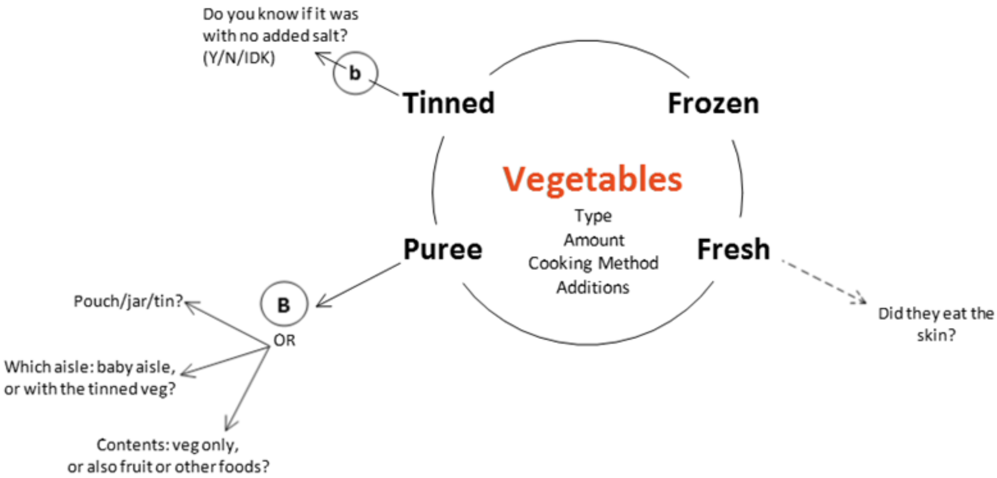
Part Two: Probing prompts, detail cycle

Probing Questions: For every food identified, determine the TYPE, AMOUNT and any ADDITIONS.

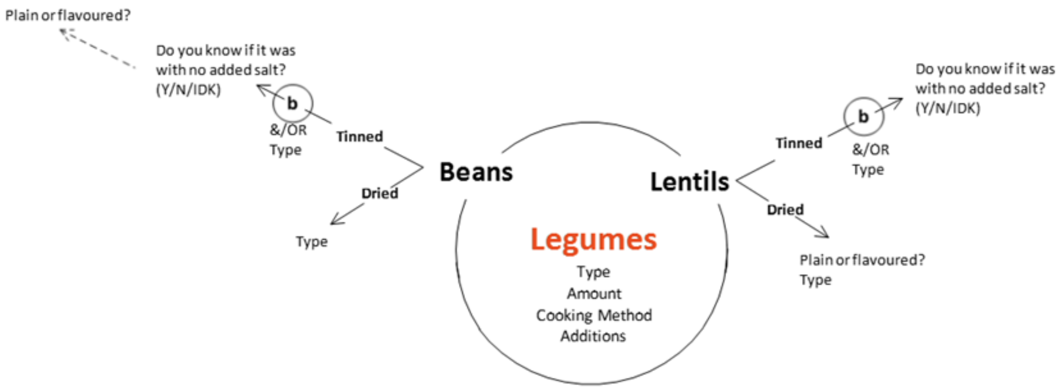
TYPE	**Where possible, getting the exact brand and product is preferred.** For example, Stringers Cheese stick. This is more important for foods that have a high variability between products. For example, white bread has relatively similar nutritional content (size/thickness is the biggest variant), whereas orange juice does not. **Foods where the brand doesn't really matter are generally core foods**, such as milk (need fat content and plain or flavoured), grain staples (need brown vs white) meat (need cut and fat trim), eggs, Nuts (salted/roasted), etc. Don't waste subject burden asking about the brand if they seem impatient. **Foods where the brand is valuable are generally processed foods, but include some specialty core items** such as cheese sticks, yoghurt and fruit purees. **Try to get brands on toddler foods.** **If the participant doesn't know the exact brand and product, get a general description and probe for key details.** Probe more on the variant foods (eg sliced white bread vs 100% Orange Juice: no pulp, no added sugar, long life) Use the probing images to give you an idea of key probes for each food. Note, these are only a starting point.
AMOUNT	**Let the participant identify the unit of measure for each item, by asking a general "how much" question.** They can give answers in number of items (eg 1 slice of bread, 2 dried apricot halves), volume (mL), standard cups etc, as long as the measure is universally understood or standardised in some way. Eg "a small bowl" of chips is not an ideal measure, while "a small fries" from McDonalds is fine. Get creative in negotiating the size if they are having difficulty finding universal measures. Questions like: was it about the size of a tennis ball? Or a pack of cards? But make sure the dimensions are similar eg if round/blobby give round comparison etc. Refer to stock images provided to the participants for reference if useful.
ADDITIONS	**Let the participant identify additions, by asking a general "did you add anything to the food" question.** But it may be appropriate to probe if they say 'no', something like "any butter or other spreads or anything?" If they say no, try to only probe once, but it can have multiple suggestions, eg "so there was no toppings or chopped nuts or fruit on top or anything?"



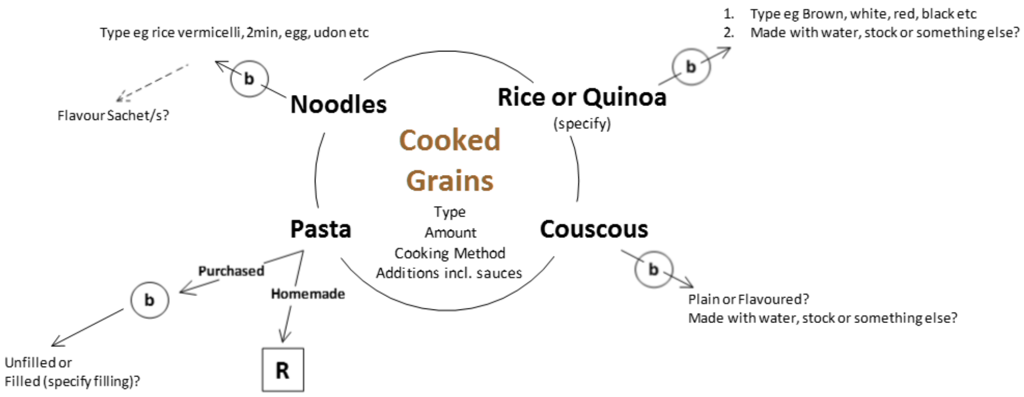
ADDITIONS:
Did you add anything to the fruit?
Did you serve it with ice cream or yoghurt, or with honey or anything else?



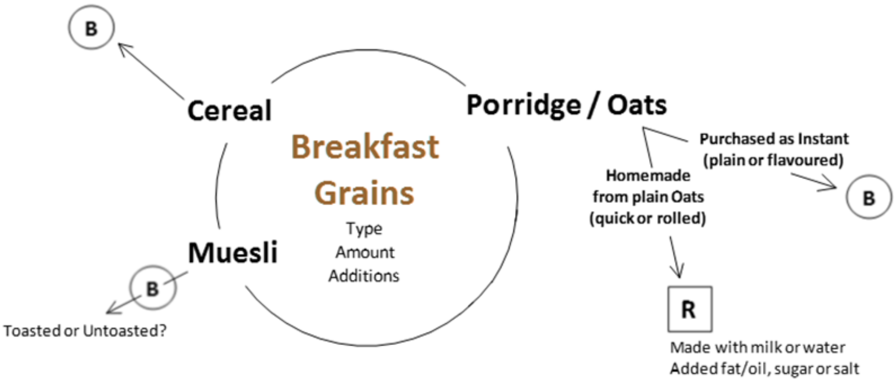
ADDITIONS:
Did you add anything to the <food>?
Did you serve it with butter, or with sauce or dressing or anything else?



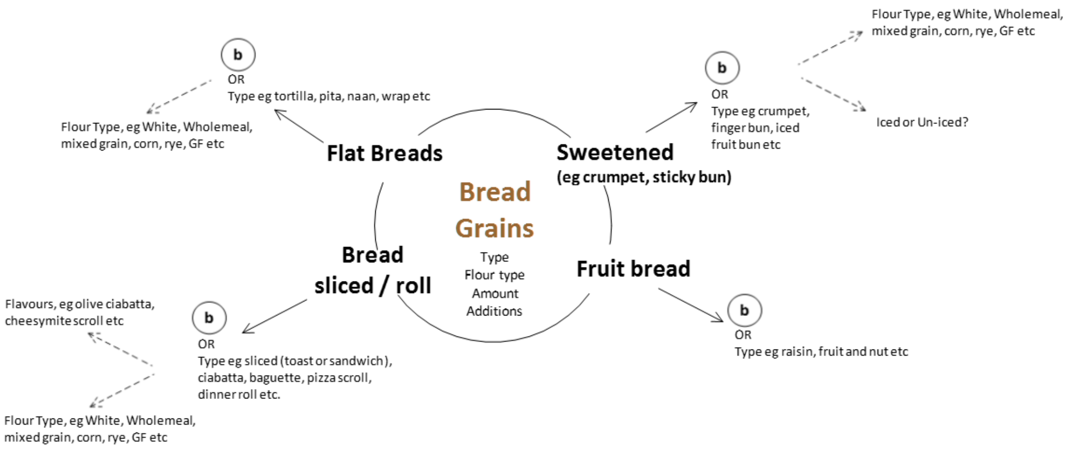
ADDITIONS:
Did you add anything to the <food>?
Did you add any salt, fat or oil to the cooking water?
Did you serve it plain, or did you add sauce, toppings etc?



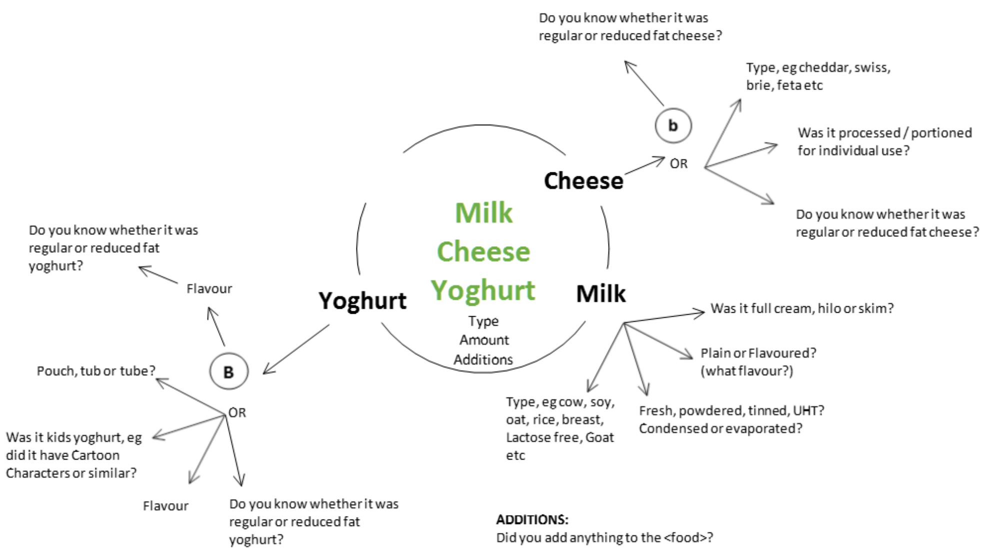
ADDITIONS:
Did you add anything to the <food>?
Did you add any salt, fat or oil to the cooking water?
Did you serve it plain, or did you add sauce, toppings etc?
Did you serve it with anything else, like cheese or sour cream?

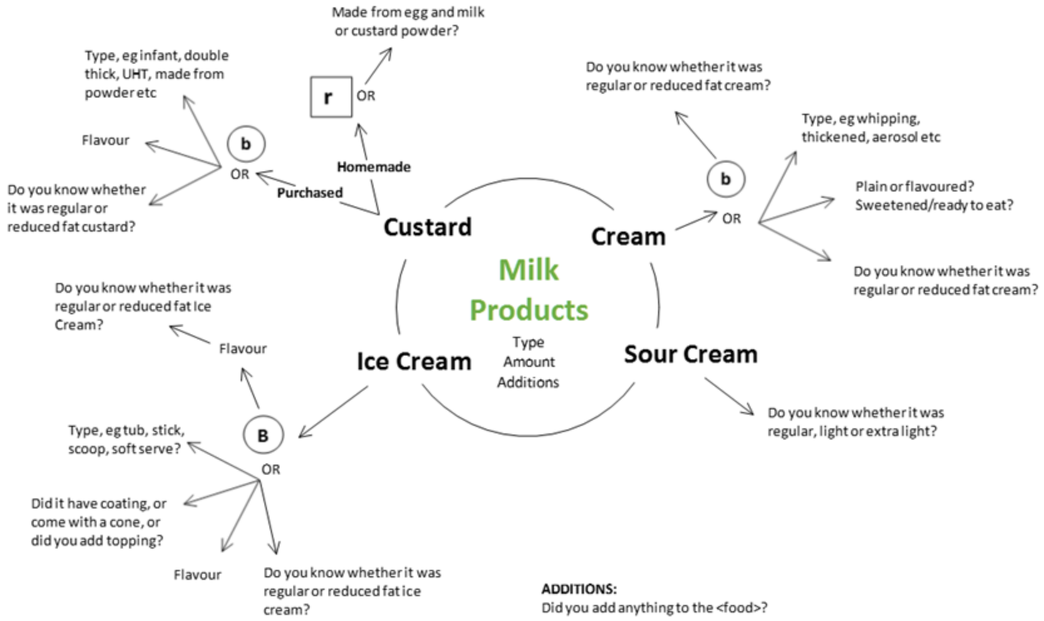


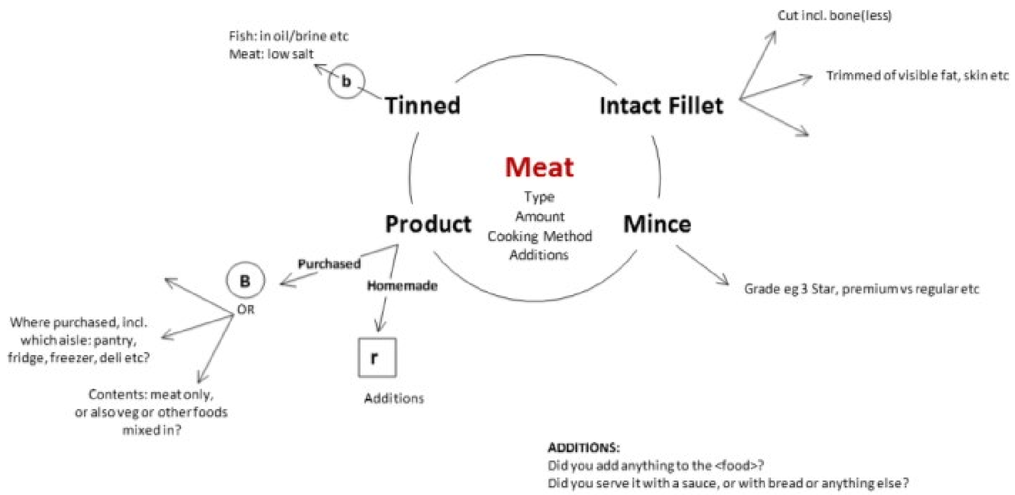
ADDITIONS:
Did you add anything to the <food>?
Did they have it dry or with milk, yoghurt or anything else?
Did you top it with sugar, honey or anything else?
Did you serve it with fruit or anything else?

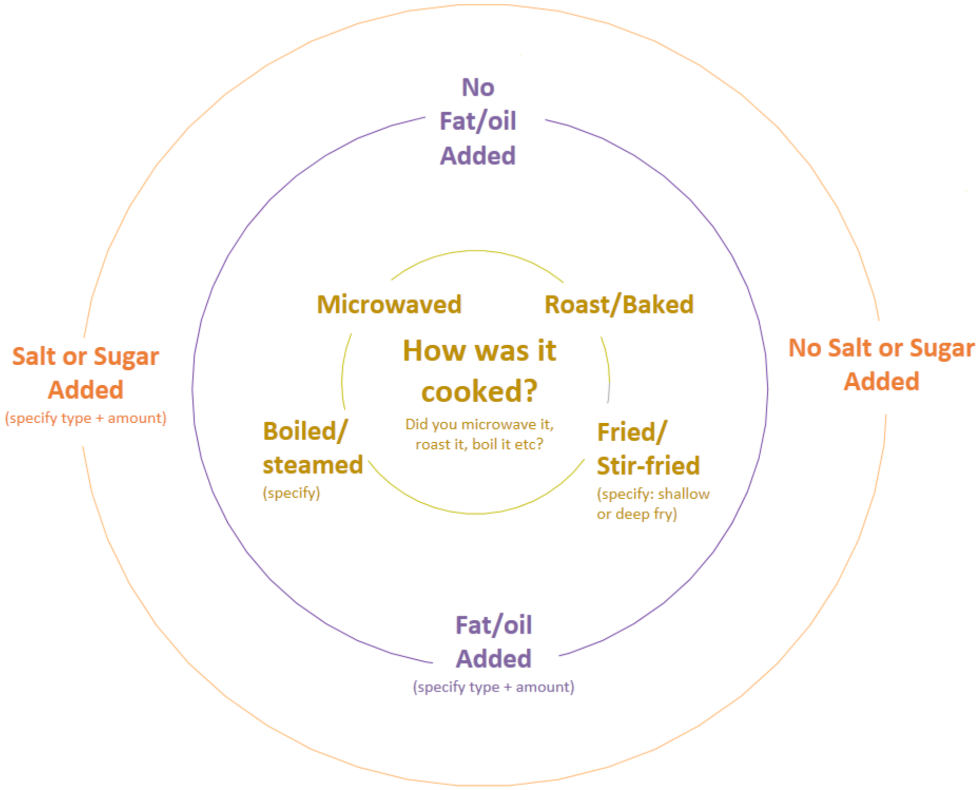


ADDITIONS:
Did you add anything to the <food>?
Did you serve it with butter or margarine, or with honey or anything else?


Milk
Cheese
Yoghurt
Type
Amount
Additions
Cheese
b
OR
Do you know whether it was regular or reduced fat cheese?
Type, eg cheddar, swiss, brie, feta etc
Was it processed / portioned for individual use?
Do you know whether it was regular or reduced fat cheese?
Milk
Was it full cream, hilo or skim?
Plain or Flavoured? (what flavour?)
Fresh, powdered, tinned, UHT? Condensed or evaporated?
Type, eg cow, soy, oat, rice, breast, Lactose free, Goat etc
Yoghurt
B
OR
Do you know whether it was regular or reduced fat yoghurt?
Flavour
Pouch, tub or tube?
Was it kids yoghurt, eg did it have Cartoon Characters or similar?
Flavour
Do you know whether it was regular or reduced fat yoghurt?
ADDITIONS:
Did you add anything to the <food>?


Milk
Products
Type
Amount
Additions
Custard
Made from egg and milk or custard powder?
r
OR
Homemade
Purchased
b
OR
Type, eg infant, double thick, UHT, made from powder etc
Flavour
Do you know whether it was regular or reduced fat custard?
Cream
b
OR
Do you know whether it was regular or reduced fat cream?
Type, eg whipping, thickened, aerosol etc
Plain or flavoured? Sweetened/ready to eat?
Do you know whether it was regular or reduced fat cream?
Sour Cream
Do you know whether it was regular, light or extra light?
Ice Cream
B
OR
Do you know whether it was regular or reduced fat Ice Cream?
Flavour
Type, eg tub, stick, scoop, soft serve?
Did it have coating, or come with a cone, or did you add topping?
Flavour
Do you know whether it was regular or reduced fat ice cream?
ADDITIONS:
Did you add anything to the <food>?


Meat
Type
Amount
Cooking Method
Additions
Tinned
b
Fish: in oil/brine etc
Meat: low salt
Intact Fillet
Cut incl. bone(less)
Trimmed of visible fat, skin etc
Mince
Grade eg 3 Star, premium vs regular etc
Product
Purchased
Homemade
B
OR
Where purchased, incl. which aisle: pantry, fridge, freezer, deli etc?
Contents: meat only, or also veg or other foods mixed in?
r
Additions
ADDITIONS:
Did you add anything to the <food>?
Did you serve it with a sauce, or with bread or anything else?



Common Formula Brands

S26 Gold
S26 Original
Karicare **Aptamil Gold**
Karicare +
Nestle **NAN Pro**
Nestle **NAN H.A.**
A2 Platinum
Bellamy's Organic
SMA
Heinz **Nurture** Original
Heinz **Nurture** Gold

Notes:
Many of these come in a range of ages/steps and special formulations - ensure you clarify. Also clarify whether it was soy, goat milk or any other milk alternative.

Teething Rusks or Milk Rusks
Common Rusk Brands

Bellamy's Organic Toothiepegs teething rusks
Heinz Teething Rusks or **Heinz** Vegetable Teething Rusks
Heinz All-Round Rusks
Only Organic Teething Rusks
Organic 4 Kids Gluten Free teething rusks
Rafferty's Garden Banana Milk Rusks

Rice Rusks
Baby Mum-Mum Rice Rusks ™, Baby Macro Wholefoods Organic Baby Rice Rusks etc

Common Brands & products

Jars	Pouches	Tins
	 	
Vanilla Custard 6+ Months Glass Jar	Vanilla Custard 6+ Months	Vanilla Custard Baby Food Value Pack Cans

Junior Apple Fruit Drink Tetra 4 pack

Organic Apple & Blackcurrant Fruit Drink

Common Brands & products

Jars	Pouches	Dry cereal
		
Porridge Creamy Banana Cereal 6+ Months	Banana & Apricot Cereal Baby Food	Cerelac Wheat Cereal Stage 2 6-12 Months
		
Apple & Blueberry Muesli Cereal Glass Jar 6+ Months	Breakfast On The Go Oatmeal & Apple Baby Food Cereal	Original Baby Cereal 7-9 Month

Appendix F INFANT FOODS LIST

Infant Food Name	Added sugars estimate (g)	Free sugars estimate (g)
Annabel Karmel apple peach banana & strawberry puree	0	1
Annabel Karmel Apple, Pear & Cinnamon puree	0	0
Annabel Karmel chicken & Apple bites	0	0
Annabel Karmel chicken & pumpkin risotto	0	1.7
Annabel Karmel frozen beef lasagne	0	1
Annabel Karmel frozen coconut pudding	4.5	4.5
Annabel Karmel frozen fish pie	0	1
Annabel Karmel Frozen Spaghetti & Meatballs	0.82	1
Annabel Karmel pear mango & strawberry puree	0	1
Annabel Karmel pureed bolognese	0	0
Annabel Karmel pureed lentils & vegetables	0	0
Annabel Karmel stage 1 apple & blueberry puree	0	1
Baby Macro Organic Apple, banana & blueberry bircher muesli 8 months	0	0
Baby Macro Organic Banana, mango, apple with Greek-style yoghurt 6 months	0	0.27
Baby Macro Organic Beef with vegetables & rice 8 months	0	0
Baby Macro Organic Chicken with sweetcorn & pasta 6 months	0	0
Baby Macro Organic Lamb & vegetable casserole 8 months	0	0
Baby Macro Organic Lamb with sweet potato 6 months	0	0
Baby Macro Organic Pear, banana & berries with Greek-style yoghurt 6 months	0	0
Baby Macro Organic Pumpkin, spinach, ricotta & pasta 6 months	0	0
Baby Macro Organic sweet vegetables puree 6 months	0	0
Baby Macro Organic vegetable risotto 8 months	0	0
Baby Mum-Mum Rice Rusks	0	12.8
Baby-O, 3 bean & vegetable casserole, 10 months	0	0
Baby-O, Beef hot pot, 6 months	0	0
Baby-O, chicken & sweetcorn with pasta, 6 months	0	0
Baby-O, curry chicken with basmati rice, 10 months	0	0
Baby-O, milk chocolate custard, 6 months	6.6	6.6
Baby-O, organic minted lamb with vegetable, 10 months	0	0
Baby-O, organic puree: Creamy pumpkin & spinach with pasta, 6 months	1.2	1.2
Baby-O, vanilla bean custard, 6 months	3.5	3.55
Bellamy's Fruit Pouch (mango blueberry apple)	0	0
Bellamy's Organic Apple Snacks 12 months (unsweetened dried apple)	0	0
Bellamy's, organic apple & cinnamon porridge, 6 months	0	0.75

Infant Food Name	Added sugars estimate (g)	Free sugars estimate (g)
Bellamy's, organic brocolli beef & brown rice, 6 months	0	0
Bellamy's, organic chicken, sweet potato & couscous, 6 months	0	0
Bellamy's, organic spring vegetable macaroni, 6 months	0	0
Calogen Neutral high energy supplement	0	0
Farex breakfast on the go creamy baby porridge 6 months	0	3.14
Farex Dinners, Multigrain with Cauliflower, Broccoli, cheese (made up with water) 6 months	0	0
Farex muesli with apple (made up with milk) 9 months	0	0
Farex muesli with apple (made up with water) 9 months	0	0
Farex muesli with pear & banana (made up with water) 6 months	0	0
Farex original multigrain cereal (made up with water) 6 months	0	0
Fruit poles (98% fruit)	0	0.9
Fruit strap 100%	0	0
Goat milk formula, prepared	0	0
Heinz Biscottini	27	27
Heinz Fruit Puree Pouch (pear berry banana)	0	0
Heinz Little Kids Fruit Bar (Apple Muesli)	39.4	39.4
Heinz Little Kids Tomato corn cakes	0	0
Heinz Nutrios	0	0
Heinz Shredz	0	18.2
Heinz vanilla custard (pouch), 6 months	7	7
Heinz, alphabet pasta, tomato & beef, 8 months	0	0
Heinz, apple & banana cereal, 6 months	0	4
Heinz, apple & blackcurrant gel, 6 months	0	8.9
Heinz, apple & blueberry muesli, 6 months	0	2.9
Heinz, Apple & Oatmeal, 6 months	0	1
Heinz, apple, peach & passionfruit rice pudding, 8 months	0	0
Heinz, apple, pear & cinnamon porridge, 8 months	0	0
Heinz, apple, sweet potato & mango, 6 months	0	0
Heinz, baby bircher with apple & blueberry, 6 months	5.1	5.1
Heinz, banana mango muesli with Greek-style yoghurt, 12 months	0	0
Heinz, banana, mango, berry, 6 months	0	2.7
Heinz, Banana, mango, zucchini & spinach puree, 6 months	0	0
Heinz, beef & vegetable casserole, 8 months	0	0
Heinz, brekky-to-go berry & pear muesli with Greek-style yoghurt, 12 months	5.1	5.1
Heinz, Butternut pumpkin pilaf, 8 months	0	0
Heinz, Chicken & pumpkin rice, 12 months	0	0

Infant Food Name	Added sugars estimate (g)	Free sugars estimate (g)
Heinz, chicken & vegetable risotto, 8 months	0	0
Heinz, chicken, sweetcorn & mango, 6 months	0	0
Heinz, chicken, tomato & mushroom casserole, 8 months	0	0
Heinz, choc custard, 6 months	5.5	5.5
Heinz, Choccherry coconut custard, 8 months	6.1	6.1
Heinz, creamy banana porridge, 6 months	0	2.5
Heinz, creamy oats with fig & sultanas, 6 months	1	1
Heinz, creamy pasta & tuna mornay, 8 months	0	0
Heinz, Custard with Banana (jar or tin), 6 months	4.3	4.3
Heinz, custard with banana (pouch), 6 months	7.5	7.5
Heinz, egg custard, 6 months	4.58	4.58
Heinz, Fruity Berries with Greek-style yoghurt, 6 months	0	0
Heinz, Glass gel summer fruit, 6 months	0	13
Heinz, Lamb & Vegetable with ricotta, 6 months	0	0
Heinz, Little kidz beef & vegetable casserole, 12 months	0	0
Heinz, Macaroni & meatballs, 12 months	0	0
Heinz, Organic beef, pumpkin, spinach & rice, 6 months	0	0
Heinz, Organic mini Apple Rice Cakes	0	18.7
Heinz, organic range pumpkin & ricotta with spinach, 8 months	0	0
Heinz, Pasta chicken & vegetables, 12 months	0	0
Heinz, pear & banana, 8 months	0	0
Heinz, pear, orange & pineapple, 8 months	0	3.03
Heinz, pumpkin, vegetable & couscous, 8 months	0	0
Heinz, Ravioli bolognaise, 12 months	0	0
Heinz, savoury rice & beef, 12 months	0	0
Heinz, spaghetti bolognaise, 12 months	0	0
Heinz, spring lamb with vegetable mash, 8 months	0	0
Heinz, Strawberry & Vanilla Custard, 8 months	7	7.15
Heinz, strawberry rice & yoghurt, 8 months	0	4.17
Heinz, Summer fruits & yoghurt with oats & quinoa, 8 months	0	2.9
Heinz, Tender beef & vegetables, 12 months	0	1
Heinz, tender beef with vegetable mash, 8 months	0	0
Heinz, Vanilla Custard (jar or tin), 6 months	5.9	5.9
Lactose Free Formula Powder	0	0
Little Bellies Animal Biscuits	0	19.5
Nestle, Cerelac Infant cereal: Muesli with pear, 8 months, prepared with water	0	0.59
Nestle, Cerelac Infants cereal: Muesli with pear, 8 months, dry powder	0	0.59

Infant Food Name	Added sugars estimate (g)	Free sugars estimate (g)
Nestle, Cerelac Infants cereal: oats with prunes & probiotics, 6 months, dry powder	0	0
Nestle, Cerelac Infants cereal: oats with prunes & probiotics, 6 months, prepared with water	0	0
Nestle, wheat with probiotics, 6 months, dry powder	0	0
Nestle, wheat with probiotics, 6 months, prepared from dry with water	0	0
Once upon a time Woolworths dessert apple crumble 12 months	0	0
Once upon a time Woolworths dessert banana choc custard 6 months	7.82	7.82
Once upon a time Woolworths dessert banana custard 6 months	7.42	7.42
Once upon a time Woolworths dessert rice pudding with pear & mixed berries 12 months	0	0
Once upon a time Woolworths dessert strawberry custard 6 months	7.74	7.61
Once upon a time Woolworths mealtime harvest vegetables 8 months	0	0
Once upon a time Woolworths mealtime hearty beef stew 8 months	0	0
Once upon a time Woolworths mealtime potato, pumpkin & beef casserole 6 months	0	0
Once upon a time Woolworths mealtime vegetable pasta bake 6 months	0	0
Only Organic apple banana & mango 6 months	0	0
Only Organic apple berry & vanilla 9 months	0	0
Only Organic apple peach & apricot 6 months	0	1.5
Only Organic banana berries & yoghurt 9 months	0	0
Only Organic banana blueberry & quinoa 6 months	0	0
Only Organic banana, raspberry & vanilla 9 months	0	0
Only Organic carrots red lentils & cheddar 9 months	0	0
Only Organic cauliflower broccoli & cheddar 6 months	0	0
Only Organic chicken bolognese 9 months	0	0
Only Organic chocolate custard 9 months	7.74	7.74
Only Organic creamy rice pudding 9 months	8.16	8.16
Only Organic fruit muesli 6 months	0	0.39
Only Organic Fruit Puree (apple banana mango)	0	0
Only Organic golden fruit porridge 6 months	0	0
Only Organic mango & yoghurt brekkie 9 months	0	0
Only Organic mango banana bliss 6 months	0	6.3
Only Organic mango rice pudding 9 months	0	4.5
Only Organic Mini Rice Cakes, Blueberry & Carrot	0	15.1
Only Organic minted peas blackcurrant & lamb 9 months	0	0
Only Organic oatie apple brekkie 9 months	0	2.7
Only Organic pear banana & apple 6 months	0	0
Only Organic pumpkin potato & beef 6 months	0	0

Infant Food Name	Added sugars estimate (g)	Free sugars estimate (g)
Only Organic tender beef & veg 6 months	0	0
Only Organic vanilla bean custard 6 months	6.36	6.36
Only Organic vegetable chicken risotto 9 months	0	0
Only Organic vegetable lasagne 9 months	0	0
Only Organic wild rice risotto & spring lamb 6 months	0	0
Organic bubs, blueberry & apple amaranth with Greek-style yoghurt, 6 months	0	0
Organic bubs, blueberry & banana quinoa, 6 months	0	0
Organic bubs, chicken & sweetcorn risotto, 7 months	0	0
Pediasure Tetra	3.76	3.76
Pedisaure Powder	21	21
Potato Stix	0	0
Rafferty's garden apricot chicken baby puree 6 months	0	0
Rafferty's Garden baby's bolognese with macaroni 10 months	0	0
Rafferty's Garden bangers, mash & veggie puree 6 months	0	0
Rafferty's Garden beef casserole 10 months	0	0
Rafferty's Garden beef with veggies & basmati rice baby mash 8 months	0	0
Rafferty's Garden chicken basil & tomato pasta 10 months	0	0
Rafferty's Garden creamy chicken & veggies (puree) 6 months	0	0
Rafferty's Garden Fruit Pouch (apple pear cinnamon)	30.2	35
Rafferty's Garden Fruit snack Bar (blueberry apple banana oat)	0	0
Rafferty's Garden hearty beef & veggie puree 6 months	0	0
Rafferty's Garden Just Veggies pouch	0	0
Rafferty's Garden macaroni, cheese & veggies (baby mash) 8 months	0	0
Rafferty's Garden mild butter chicken 12 months	0	0
Rafferty's Garden Moroccan lamb 12 months	0	0
Rafferty's Garden multigrain banana & apricot cereal 6 months (RTE & made from powder)	0	0
Rafferty's Garden organic baby's banana porridge RTE 6 months	0	0
Rafferty's Garden pouch sweet potato carrot & apple	0	0
Rafferty's Garden risoni pasta & garden veggies 10 months	0	0
Rafferty's Garden shepherd's pie 10 months	0	0
Rafferty's Garden teriyaki chicken, veggies & rice 12 months	0	1.165
Rafferty's Garden vegetable risotto 8 months	0	0
Rafferty's Garden Yoghurt Buttons (Strawberry)	18.6	18.6
Rafferty's Garden sweet potato & lamb casserole 10 months	0	0
Rice Cake Yoghurt Coated (Table of Plenty Triple Berry)	31.79	31.79
Soy Formula Powder	0	0

Infant Food Name	Added sugars estimate (g)	Free sugars estimate (g)
SPC Fruit Crush Ups	0	6.2
SPC Fruity Jelly pouch	20.1	21.4
Tomato Sauce No Added sugar	0	0
Yoghurt Coles Kids (Strawberry & Vanilla Flavours)	6.2	6.2
Yoghurt, CalciYum Character	5.64	5.64
Yoghurt, Petit Miam (Squeezies Pouch or tub)	5.51	5.51
Yoghurt, Vaalia Kids (Vanilla, Strawb. Tropical)	5.37	5.37
Yoghurt, Vaalia My First Yoghurt (Vanilla & Strawb)	4.54	4.54
Yoghurt, Vanilla, five:am brand	5.84	5.84

Appendix G SMILE-FFQ INVALID RESPONSE PROTOCOL

The online version of SMILE-FFQ had validation functions that prevented participants from giving invalid responses. This protocol was employed for data entry of paper-based SMILE-FFQ, where invalid responses were provided.

First:

Look at total number of invalid responses. If greater than or equal to 5% invalid, follow the below protocol, but flag separately (for possible exclusion).

Second:

If it is a FREQUENCY question (Q number usually ends in _1):

If their response is “1” (never or rarely) + another frequency value, AND

1. they have entered a response to the corresponding AMOUNT question: ignore the “1” and accept the other frequency value
2. there is no response in the AMOUNT question: accept the “1” response

Third:

For the remaining (unresolved) frequency questions and all amount questions:

3. If there are two adjacent responses, take the lower of the two
   eg if response is both 3+4, take 3
4. If they are disparate, take the middle value (or the lower of the two middle values if required)
   eg if response is 3+5, enter 4;
   if 3+7, enter 5;
   if 3+6, enter 4

Appendix H TABLE 4.8 - ENLARGED VERSION

The condensed version of Table 4.8 appears on page 138.

	Non-Respondents			Respondents			Respondents with Free Sugars <5% of Energy			Respondents with Free Sugars ≥5% of Energy			Respondents with Free Sugars ≥10% of Energy		
	n	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*	mean	SD
Mother's age at birth (years)	1275	29.2	5.6	826	30.8	4.9	637	31	4.8	189	30	5.3	20	28.1	6.9
Total number of children	1066	1.9	1	801	1.7	0.9	615	1.7	0.8	186	1.8	1	20	2	1.2
Child's birthweight (g)	1265	3328.4	578.6	818	3397.9	558.1	632	3396.5	571.1	186	3402.6	513	20	3370.8	428.5
Child's age at 24HR (months)	0			807	13.1	0.8	625	13.1	0.8	182	13.2	0.9	20	13.1	0.9
	n	%		*n*	%		*n*	%		*n*	%		*n*	%	
Child's sex															
Male	694	51.5		452	54.6		335	52.4		117	61.9		12	60	
Female	653	48.5		376	45.4		304	47.6		72	38.1		8	40	
Milk feeding method															
Breastfeeding only	NA			220	26.6		181	28.3		39	20.6		5	25.0	
Breastfeeding and formula	NA			68	8.2		57	8.9		11	5.8		0	0	
Formula only	NA			310	37.4		235	36.8		75	39.7		7	35.0	
Neither	NA			230	27.8		166	26		64	33.9		8	40.0	
Mother's pre-pregnancy BMI[a] (kg/m^2)															
< 18.5	57	5		41	5.2		36	5.9		5	2.9		0	0	
18.5–24.99	552	48		436	55.6		343	56		93	54.1		10	55.6	
25–29.99	288	25.1		167	21.3		126	20.6		41	23.8		2	11.1	
≥ 30	252	21.9		140	17.9		107	17.5		33	19.2		6	33.3	
Mother's smoking status at 12 months															

	n	%	n	%	n	%	n	%	n	%
No	419	90.5	746	92	576	92.2	170	91.4	16	80
Yes	44	9.5	65	8	49	7.8	16	8.6	4	20

continued

	n	%	n	%	n	%	n	%	n	%
Total number of children										
1	474	44.5	389	48.6	299	48.6	90	48.4	11	55
2	379	35.6	291	36.3	229	37.2	62	33.3	3	15
≥ 3	213	20	121	15.1	87	14.1	34	18.3	6	30
Mother's education										
Some high school	228	17.8	61	7.4	38	6	23	12.3	4	20
Completed high school	192	15	83	10.1	53	8.3	30	16	4	20
Some vocational training	80	6.2	36	4.4	26	4.1	10	5.3	3	15
Completed vocational training	280	21.9	176	21.4	137	21.5	39	20.9	5	25
Some university or college	75	5.9	85	10.3	64	10	21	11.2	1	5
Completed university/college	269	21	246	29.9	200	31.4	46	24.6	3	15
Postgraduate	156	12.2	137	16.6	119	18.7	18	9.6	0	0
Household income ($)										
≤ 40,000	299	25.1	92	11.5	57	9.3	35	19	9	45
40,001–80,000	429	36	254	31.8	192	31.3	62	33.7	7	35
80,001–120,000	295	24.7	254	31.8	199	32.4	55	29.9	4	20
≥ 120,000	170	14.2	198	24.8	166	27	32	17.4	0	0
IRSAD[b]										
Deciles 1–2	342	27.2	120	14.6	83	13.1	37	19.6	3	15
Deciles 3–4	273	21.7	173	21	118	18.6	55	29.1	7	35
Deciles 5–6	216	17.2	174	21.2	144	22.7	30	15.9	1	5
Deciles 7–8	225	17.9	160	19.5	133	21	27	14.3	3	15
Deciles 9–10	203	16.1	195	23.7	155	24.5	40	21.2	6	30
Mother's country of birth										
Australia or New Zealand	843	66.2	610	74.1	459	72.4	151	79.9	17	85
United Kingdom	46	3.6	31	3.8	23	3.6	8	4.2	2	10

India	136	10.7	50	6.1	38	6	12	6.3	0	0
China	28	2.2	37	4.5	37	5.8	0	0	0	0
Asia-other	123	9.7	52	6.3	45	7.1	7	3.7	0	0
Other	98	7.7	43	5.2	32	5	11	5.8	1	5

[a] Body Mass Index (kg/m^2, where < 18.5 = underweight; 18.5–24.99 = healthy weight range; 25–29.99 = overweight; ≥ 30 = obese) [b] Index of Relative Socio-economic Advantage and Disadvantage (where 1 = most disadvantaged and 10 = least disadvantaged) NA = data not available