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Sources and determinants of free sugars intake by 5-year-old Australian children in the SMILE cohort

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Abstract

Reducing free sugars intake is important for the prevention of dental caries and obesity in children. The study aimed to determine the amount and sources of free sugars known to contribute to dental caries, and identify sociodemographic determinants of intake by children aged 5 years in Australia. Cross-sectional analysis of dietary data from a cohort study, collected using a customized food frequency questionnaire were used to calculate free sugars intake as grams/day and percentage contribution to Estimated Energy Requirement (EER). The percent contribution of food sources to free sugars intake was derived. Sociodemographic determinants of achieving intakes within WHO thresholds (i.e., <5% and <10% Energy were explored with multinomial logistic regression. Complete data were available for 641 children (347 boys, 294 girls). Median (IQR) free sugars intake (g/day) was 31.6 (21.3–47.6) in boys and 28.1 (19.6–47.9) in girls. The median (IQR) percentage contribution to EER was 7.9 (5.4–12.7); 21% and 42% of children had intakes <5% EER and between 5% and <10%, respectively. The main sources of free sugars were: (1) Cakes, Biscuits and Cereal Bars; (2) Sweetened Milk Products (predominantly yoghurts) and (3) Desserts. Maternal university education, single-parent household, and maternal place of birth being Australia or New Zealand were associated with free sugars intake <5% EER. In conclusion, less than a quarter of 5-year-old children in the SMILE cohort achieved the WHO recommendations to limit free sugars to <5% EER. Strategies to lower free sugars intake could target priority populations such migrants, populations with lower levels of education or health literacy and identify areas for intervention in the wider food environments that children are exposed to.

KEYWORDS
determinants, diet, early childhood, food, food frequency questionnaire, food sources, survey

1 | INTRODUCTION

There is evidence that intake of free sugars is a risk factor for overweight or obesity and a direct cause of dental caries (i.e., tooth decay) (WHO, 2003). Among 5–9-year-olds, in Australia, approximately one quarter of children are living with a weight classified as overweight (17%) or obesity (7%) (Australian Institute of Health and Welfare, 2020) and nearly half (42%) children experience dental caries (Australian Institute of Health and Welfare, 2021; Ha et al., 2016). Reducing the intake of free sugars is important for the prevention of dental caries and excess weight gain (Moynihan & Miller, 2020; Te Morenga et al., 2012; World Health Organization, 2017). To develop dietary interventions to lower the intake of free sugars, information on the amount, sources and social determinants of free sugars intake in children is essential.

The World Health Organization (WHO) recommends limiting the intake of free sugars to less than 10% energy intake (EI) and preferably to below 5% to protect oral health throughout the life course (World Health Organization, 2015). Free sugars include all monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, fruit juices and fruit juice concentrates (World Health Organization, 2015). Free sugars make a sizeable contribution to total dietary sugars (Rugg-Gunn et al., 2007). Total sugars include free sugars and the sugars naturally present in whole fruits, vegetables and milk (Rugg-Gunn et al., 2007). Free sugars intake in children exceeds the WHO recommended thresholds in many countries. For instance, in the United Kingdom (UK) and Lebanon, free sugars contributed to an average 12% of EI in children aged <10 years (Amoutzopoulos et al., 2020; Jomaa et al., 2021), 14% EI in 2–5-year-old children in the United States (Dietary Guidelines for Americans, 2020) and Japan (Fujiwara et al., 2021), 16% in French (Deshayes et al., 2021) 3–6-year-old children and 27% in German preschool children (Graffe et al., 2020). The most recent national survey in Australia in 2012 showed that children (4–8-year-old) obtained 14% EI from free sugars (Australian Bureau of Statistics, 2017).

Sociodemographic factors have been shown to influence food intake, including intake of free sugars. Data on the specific sociodemographic factors that determine amount and sources of free sugars intake are available from UK (Amoutzopoulos et al., 2020), Japan (Fujiwara et al., 2021), some European Countries (Graffe et al., 2020), Canada (Bergeron et al., 2019) and Latin American countries (Fisberg et al., 2018) showing that education, income and family composition are key determinants of free sugars intake in children. Data are also available from the 2012 Australian National Survey, showing that children from families living with disadvantage consumed greater amounts of free sugars (Australian Bureau of Statistics, 2017). However, these data do not provide information on sociodemographic factors associated with achieving intakes of free sugars within the WHO recommended thresholds. The sources of free sugars intake are diverse and change rapidly as children age. Information on the sources of free sugars intake is important for informing dietary intervention. For dental caries prevention, it is important to restrict the foods and drinks containing free sugars, especially those that tend to be consumed between meals, when salivary flow is relatively low (e.g., sugar-sweetened beverages (SSB), confectionery, biscuits, cakes and cereal bars, and dried fruits) (Moynihan & Petersen, 2004; Moynihan et al., 2009; Sheiham, 2001). In the UK (Amoutzopoulos et al., 2020), USA (Dietary Guidelines for Americans, 2020), European countries (Graffe et al., 2020) and Mexico (Afeiche et al., 2018) recent studies have shown that children obtain a large proportion of free sugars from SSBs including sweetened juices. Furthermore, cakes, biscuits, cereal based products and confectionery were the leading contributors of free sugars intake by children in Portugal (Marinho et al., 2020), Lebanon (Jomaa et al., 2021) and China (Afeiche et al., 2018). The 2012 national data on the dietary sources of sugars in Australian 2–17-year-olds showed that added sugars were sourced from soft drinks, confectionery and cakes (Australian Bureau of Statistics, 2017). However, as diet in early childhood impacts on the longer-term risk of dental caries (Karjalainen et al., 2015) it is important to have specific data on the level of intake, sources and determinants of free sugars intake to guide early intervention for caries prevention.

The SMILE (Study of Mothers' and Infants' Life Events Affecting Oral Health) cohort includes 2181 infants recruited at birth in Adelaide, South Australia. The SMILE cohort study aims to understand the critical factors that influence oral health and to gain knowledge of the link between diet, sociodemographic factors and oral health in early life. Participants were followed up at 3 and 6 months and at 1, 2 and 5 years of age (Do et al., 2020). Previous analysis (Devenish, Golley, et al., 2019; Devenish, Ytterstad, et al., 2019; Do et al., 2020; Ha et al., 2017) based on the Food Standards Australia and New Zealand Nutrient (AUSNUT) database codes (Food Standards Australia New Zealand, 2011) showed that infant foods and cereal-based snacks like biscuits were the leading sources of free sugars intake at 12–14-months (Devenish, Ytterstad, et al., 2019) and beverages, cakes and biscuits at 2 years of age (Devenish, Golley, et al., 2019). At 1 year of age, free sugars contributed 3.6% of the Estimated Energy Requirement (EER) and 8% EER at 2 years of age. Household disadvantage and low income were associated with exceeding the WHO recommended threshold for

Key messages

- Children in the SMILE cohort have some way to go to reach the WHO recommendation to limit the intake of free sugars to less than 5% E.
- Cakes, Biscuits, Cereal Bars, Sweetened Milk Products and Desserts were the principal contributors to free sugars intake by children aged 5 years.
- Nutrition interventions to lower free sugars consumption are needed to support priority populations such as migrants and those with lower education.

free sugars intake at both 1 and 2 years (Devenish, Golley, et al., 2019; Do et al., 2020; Ha et al., 2017). Furthermore, at 2 years, maternal place of birth, maternal age and number of siblings were determinants of free sugars above the WHO recommended thresholds (Devenish, Golley, et al., 2019). By age 5 years, children are exposed to wider food and drink choices and the amount, sources and social determinants of free sugars may therefore change.

The aim of this paper is to report the amount, sources and determinants of free sugars intake by the SMILE study participants at age 5 years. The objectives are to: (1) estimate the amount of total and free sugars intake; (2) determine the percentage contribution to free sugars intake of groups of foods known to contribute to dental caries (e.g., foods high in free sugars that tend to be consumed between meals); and (3) identify the key sociodemographic factors associated with intakes of free sugars within the WHO recommended thresholds.

2 | METHODS

Details of the SMILE birth cohort have been described previously (Devenish, Golley, et al., 2019; Do et al., 2020; Ha et al., 2017). This cohort is representative of the socioeconomic status (SES) profile of South Australian mothers, as reported by the Australian Bureau of Statistics. A measure of SES was determined using postcode-level Index of Relative Socio-Economic Advantage and Disadvantage (IRSAD) (Do et al., 2020).

In 2013/14, 2181 mother and newborn dyads were recruited in Adelaide, South Australia. Sociodemographic data were collected at baseline. Dietary data were collected for the children at ages 1, 2 and 5 years. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Southern Adelaide Clinical Human Research Ethics Committee (HREC # 50.13, approval date: 28 February 2013), the South Australian Women and Children Health Network (HREC # HREC/13/WCHN/69, approval date: 7 August 2013). Written informed consent was obtained from all participants.

2.1 | Collection of dietary data at age 5 years

Dietary data were collected from 733 participants in 2019 at child age 5 years using the 98 item SMILE Food Frequency Questionnaire (SMILE-FFQ) (Devenish et al., 2017). In this questionnaire, six options were provided for mothers to answer the question on frequency of intake by their child, of each listed item—ranging from 'never/rarely' to 'once every 2 weeks', 'once per week', '2–3 times/week', '4–6 times/week', '1–2 times/day' and 'three times per day'. For the question on portion sizes, options were provided to report the weight/volume along with the appropriate household measures (tablespoons, teaspoons, cups, scoops, etc.). For each participant, the responses to the SMILE-FFQ were exported into a Microsoft Access database containing food composition tables adapted from the Australian Food, Supplement and Nutrient (AUSNUT) database (Food Standards Australia New Zealand, 2011). The AUSNUT database provides information on the amount in grams of total and free sugars per 100-g edible portion of different foods and drinks. The participant responses to the SMILE-FFQ were matched with the foods in the AUSNUT database to derive an estimate of the usual total and free sugars intake per participant in grams per day.

2.2 | Calculation of the percentage of energy requirement obtained from dietary sugars

The height and weight of each child were measured at age 5 years during a study visit to collect dental data. These data were used to estimate the energy requirement of each child using the US Institute of Medicine (IOM) equation (Brooks et al., 2004; Butte et al., 2014; Trumbo et al., 2002). A Physical Activity Level (PAL) of 1.6 (light activity) was assigned to all participants in accordance with previous analyses (Devenish, Golley, et al., 2019). This was based on the median value for PAL calculated from activity data reported by approximately 27% of the SMILE sample (Devenish, Golley, et al., 2019). Children with no available anthropometric data (7.5%) were split by gender and the median EER of the study group for the corresponding gender was assigned (Gerrior et al., 2006; Louie et al., 2015). For each child, EI from total and free sugars (grams of intake × 16.7 KJ) was calculated and this figure was divided by EER and multiplied by 100 to give the percentage of EER provided by total and free sugars (Louie et al., 2015).

2.3 | The percentage contribution of food sources to free sugars intake

The intention of this study was to determine the sources of free sugars intake from the perspective of dental health. Thus, although the grouping of foods for this analysis was informed by the AUSNUT food grouping classification system (Food Standards Australia New Zealand, 2011), the cariogenic potential of food items/groups informed modifications to the food group categories and labels. For example, distinguishing foods which tend to be consumed between meals from those consumed with meals, distinguishing coated dried fruits (cariogenic) from nuts (noncariogenic). The food groups used in this analysis and how these differed from the AUSNUT food codes used in Australia are defined in the supporting table. For each child, the grams of free sugars obtained from each food source was calculated as a percentage of their overall usual free sugars intake. Subsequently, the percentage contribution of each food source to free sugars intake were derived for the study population as a whole and for 'consumers only'. 'Consumers' of a food group were defined as those participants who reported any valid response other than 'never or rarely' in the SMILE-FFQ, for at least one item within the food group.

2.4 | Sociodemographic data

Sociodemographic data collected at baseline included child age and sex, maternal age, maternal education, mother's country of birth, number of children in the family and family composition (one-parent or two-parent) and postcode from which the IRSAD was derived (Devenish, Golley, et al., 2019). The IRSAD summarizes the social and economic conditions of people and households in an area, based primarily on the income and occupation.

2.5 | Statistical analyses

The distribution of total and free sugars intake was assessed as a first step. In line with earlier assessments at 2 years of age (Devenish, Golley, et al., 2019), those individuals with total or free sugars values that exceeded the 95th percentile ($n = 45$) were excluded from subsequent analysis which resulted in a data set of 688 participants. Of these, sociodemographic data were available for 641 participants. Descriptive statistics (frequencies, percentages, mean, standard deviation (SD), median, interquartile range [IQR]) were derived for sociodemographic variables, total and free sugars intake, as appropriate. Children were classified according to their percentage EER obtained from free sugars intake into the following categories: (1) <5% EER, (2) 5–<10% EER (children meeting the WHO recommended thresholds), or (3) ≥10% EER (children exceeding the WHO recommended thresholds).

The sociodemographic factors were investigated as determinants of lower free sugars intake (<5% EER, and 5–<10% EER) through multinomial logistic regression models that were fit using STATA 17.0 (Stata Statistical Software: Release 17. Stata Corp LLC). An analysis data set ($n = 641$) with complete data for all variables of interest was used for statistical analyses for these statistical models. All sociodemographic variables were included in the initial logistic regression model as explanatory variables, and retained in the final model if the corresponding overall p value was <0.2. The reference group was children with a free sugars intake ≥10% EER. The results were expressed as relative risk ratios (RRR) with associated 95% Confidence Intervals (CI). Mother's age, education, country of birth, family size, and family composition (single-parent or dual-parent) were retained as the explanatory variables.

3 | RESULTS

3.1 | Participant characteristics

The baseline participant characteristics ($n = 688$) are presented in Table 1. A large proportion of the mothers were in the 25–34 years age group and two-thirds of the mothers in this cohort attained University education or above. About half of the children had no

TABLE 1 Characteristics of the SMILE study participants.

Characteristic	Mean	SD	*n*	%	Range
Child age (years)	5.4	0.3	688		4.0–6.9
Sex					
Boys			380	55.2	
Girls			308	44.8	
Mother education					
School/vocational education			258	37.5	
University education and higher			423	61.5	
Missing			7	1.0	
Mother age (years)	30.8	5.0			
Mother age					
<25 years			55	8.0	
25–34 years			461	67.0	
≥35 years			153	22.2	
Missing			19	2.8	
Number of children in the family					
1 child			338	49.1	
2 children			242	35.2	
≥3 children			86	12.5	
Missing			22	3.2	
Family composition					
Single parent household			32	4.7	
Two parent household			650	94.5	
Missing			6	0.9	
Mother country of birth					
Australia or NZ and UK			510	74.1	
Asia except India			67	9.7	
India			56	8.1	
Other countries			47	6.8	
Missing			6	0.9	
Index of Relative Socio-Economic Advantage or Disadvantage (IRSAD)					
Quintile 1 (most disadvantaged)			99	14.4	
Quintile 2			132	19.2	
Quintile 3			149	21.7	
Quintile 4			127	18.5	
Quintile 5 (least disadvantaged)			173	25.1	
Missing			8	1.2	

TABLE 2 Total and free sugars intake (grams/day) and percentage contribution of total and free sugars to EER ($n = 688$).

Variable	Median	IQR	Mean	SD
Total sugars (g/day)	72.6	53.8–100.9	79.0	34.3
Boys	72.1	55.3–100.4	79.7	33.4
Girls	74.2	51.0–105.0	78.0	35.4
Free sugars (g/day)	29.5	20.3–48.0	35.7	21.5
Boys	31.6	21.3–47.6	36.4	21.0
Girls	28.1	19.6–48.0	34.9	22.0
Percentage contribution of total sugars to EER (%)	19.3	14.0–27.2	21.0	9.3
Boys	18.7	14.0–26.0	20.5	8.7
Girls	20.0	14.1–28.8	21.6	9.9
Percentage contribution of free sugars to EER (%)	7.9	5.4–12.7	9.5	5.8
Boys	8.0	5.4–11.9	9.3	5.4
Girls	7.8	5.3–13.2	9.7	6.2

siblings and less than 5% children belonged to single-parent households at the time of their birth.

3.2 | Data on sugars intake

Data for intake of total and free sugars were not normally distributed (Table 2). The median total and free sugars intake were 72.6 and 29.5 g/day, respectively. Children obtained a median 7.9% EER from free sugars. The data showed no statistically significant differences between boys and girls for intake of sugars and the percentage contribution of total and free sugars to the EER. About one-fifth of children (21%) achieved the WHO recommendation for the lower threshold of free sugars intake (<5% EI), 42% had free sugars intake between 5 and <10% EI, and 37% children exceeded the WHO recommendation to limit free sugars intake to less than 10% EI.

3.3 | The contribution of food sources to free sugars intake in all participants and consumers

The percentage contribution from each food group and subgroup to free sugars intake for the study population as a whole and for consumers only is presented in Table 3. The principal food sources were: (1) Cakes, Biscuits and Cereal Bars, (2) Sweetened Milk Products (Milk-based drinks, and predominantly, yoghurts), and (3) Desserts. Collectively, these food groups accounted for 52% of all free sugars intake (based on the medians for the group). Sugar and chocolate-based confectionery, SSBs, table sugar and syrups were the other sources. For consumers, Sweetened Yoghurts ($n = 544$; median 12.7%) and Beverages ($n = 503$; median 10.9%) were the leading sources contributing to free sugars intake.

3.4 | Sociodemographic determinants of free sugars intake within the WHO recommended thresholds

Complete data for the regression analyses were available for 641 participants. The results of the multinomial regression analyses (Table 4) showed that children belonging to single parent households were more likely to have a free sugars intake <5% EER compared with children from two-parent households. Children born to mothers who attended university were more likely to have free sugars intake <5% EER or between 5% and <10% EER than children born to mothers who did not have higher education. Relative to Australian and New Zealand born mothers, children born to mothers who immigrated from India, other Asian countries, and other countries were less likely to consume <10% EER from free sugars. Children belonging to families with more than three children were less likely to consume <5% from free sugars compared with single-child families.

4 | DISCUSSION

This study aimed to determine the amount and sources of free sugars intake in 5-year-old children belonging to the SMILE cohort, and to identify the key sociodemographic determinants of achieving the recommended WHO thresholds for intake of free sugars. It was found that the median free sugars intake was 29.5 g/day and the median percentage contribution to EER was 7.9%. In this study, 21% and 42% of children had free sugars intake less than 5% EI and 5–<10%, respectively. The principal sources of free sugars intake were: (1) Cakes, Biscuits and Cereal Bars, (2) Sweetened Milk Products (predominantly yoghurts) and (3) Desserts. Mother's level of education (University level), family composition (single parent households) and mother's ethnicity (being born in Australia and New Zealand) were the factors associated with a lower intake of free sugars intake by children.

The median percent contribution of free sugars to EER (7.9%) in the current study (2019) is lower than that reported in previous cross-sectional analyses, for instance, older 4–8-year-old Australian children (14%) in 2007 (Louie et al., 2016), 2–6-year-old European children in 2007/8 (18%) (Graffe et al., 2020), and 3–6-year-old French children in 2019 (16%) (Deshayes et al., 2021). The absolute intake of free sugars (29.5 g/day) in the current study is lower than the intakes reported for 2–6-year-old children in Europe (Graffe et al., 2020) and 5–9-year-old children in Portugal (44 g/day) (Marinho et al., 2020). In the current study, 63% children achieved the WHO recommended threshold to limit free sugars to <10% EI. This is higher when compared with findings from an analysis of the data from the 2007 Australian National Children Nutrition and Physical Activity Survey which showed that more than 80% of 4–8-

TABLE 3 Percent contribution of food sources to free sugars intake by 5-year-old children in the SMILE study (whole sample, *n* = 688, and in consumers only).

Food sources	All participants (*n* = 688)				Consumers only				
	Median%	IQR	Mean%	SD	Median%	IQR	Mean%	SD	*n*
Cakes, biscuits, cereal bars	23.0	12.6–3.4	24.9	15.7	7.0	3.9–12.3	25.9	15.1	660
Cakes and pastries	11.8	4.3–21.1	14.3	12.4	4.1	1.9–8.3	16.8	11.8	583
Biscuits	4.1	1.4–9.0	6.6	6.5	1.8	0.7–3.6	7.9	7.3	582
Cereal bars	0.8	0.0–5.4	3.9	6.4	1.6	0.8–3.3	7.5	7.3	356
Confectionery (Candies and chocolates)	6.4	2.9–12.3	9.0	9.5	7.5	4.2–13.3	10.3	9.5	603
Chocolates	3.1	0.8–6.6	5.1	7.1	4.5	2.3–8.1	6.6	7.4	531
Candies	2.0	0.0–5.4	3.9	5.7	4.5	2.5–8.2	6.4	6.0	427
Sugar and syrups	3.2	0.0–11.6	8.0	11.7	7.1	2.8–15.8	11.7	12.5	472
Table sugar	0.0	0.0–0.7	1.4	4.0	3.0	1.4–6.5	5.1	6.1	197
Honey and sugar syrups	1.4	0.0–8.6	6.5	11.0	6.6	2.4–15.1	11.0	12.5	409
Desserts	8.1	3.2–15.0	10.5	16.1	9.0	4.6–15.9	11.9	9.9	606
Nonfrozen milk-based desserts	0.0	0.0–2.4	2.2	5.6	3.2	1.5–5.8	5.4	7.6	286
Frozen, milk-based desserts	3.3	1.2–7.2	5.4	6.5	4.7	2.5–8.7	6.9	6.5	539
Frozen, nonmilk desserts	0.0	0.0–4.0	2.9	5.1	4.9	2.3–6.8	5.8	5.9	342
Spreads and sauces	6.6	2.4–13	9.6	10.4	7.2	3.0–13.7	10.2	10.5	647
Spreads	2.6	0.3–7.3	5.2	7.4	3.8	1.3–8.8	6.5	7.8	559
Sweet sauces	0.0	0.0	0.3	1.4	1.1	0.6–2.0	2.1	3.0	110
Savoury sauces and condiments	1.8	0.5–5.0	4.0	6.9	2.5	1.0–5.7	4.6	7.1	597
Sweetened milk products	12.0	4.1–24.4	16.5	16.1	13.7	6.0–26.8	18.5	16.0	615
Milk based drinks and alternatives	0.5	0.0–2.9	2.8	6.6	2.7	1.2–5.3	5.2	8.3	373
Yoghurt	9.2	1.4–20.7	13.7	15.1	12.5	5.8–24.4	17.4	15.1	544
Beverages	6.7	0.0–15.5	10.8	12.8	10.9	5.6–20.5	14.8	12.9	503
Sugar sweetened beverages	1.5	0.0–9.1	6.4	10.1	8.5	4.6–15.9	12.3	11.1	357
100% Fruit juices	0.0	0.0–4.4	4.2	9.0	6.9	3.8–15.7	11.6	11.8	247
Tea and coffee	0.0	0.0	0.2	1.6	7.5	3.4–11.8	9.4	8.8	12
No added sugar beverages	0.0	0.0	0.1	1.8	0.3	0.1–0.6	2.0	8.2	33
Savoury snacks and crackers	0.9	0.4–1.6	1.3	1.9	1.0	0.5–1.8	1.4	1.5	652
Breakfast cereals	0.2	0.0–1.1	1.1	2.4	0.9	0.35–2.1	1.8	2.8	419
Processed fruits and nuts	0.0	0.0–4.3	0.9	2.5	1.0	0.8–4.0	3.1	3.9	188
Processed fruit	0.0	0.0	0.7	2.1	1.5	0.7–3.5	2.8	3.6	166
Coated nuts	0.0	0.0	0.2	1.0	1.5	0.7–3.5	2.9	3.1	45

year-old Australian children exceeded this threshold (Louie et al., 2016). This difference in intake of free sugars may be explained by differences in study methodology or temporal trends as a result of increased public awareness about the harmful effects associated with the intake of sugars (Australian Bureau of Statistics, 2017). Furthermore, it is expected that the product reformulation efforts that have received media attention in recent years are likely to contribute to a further reduction in consumption of foods containing free sugars, saturated fat and sodium (Australian Bureau of Statistics, 2023; Australian Institute of Health and Welfare, 2021).

Results from the present analysis showed that Cakes, Biscuits and Cereal Bars were the leading contributors (median 23.5%) to free sugars intake. This figure is higher when compared with the reported proportion of free sugars obtained from cakes, muffins, scones and cake-type desserts (11.3%) and sweet biscuits (5.6%) by 4–8-year-old

TABLE 4 Participant characteristics associated with child achieving the recommended threshold of free sugars intake (<5% EER and 5–<10% EER) (n = 641).

Variable	Free sugars <5% EERRRR[a] (95% CI)	Free sugars 5–<10% EERRRR (95% CI)
Mother age[b]	0.99 (0.95, 1.04)	0.97 (0.94, 1.01)
Mother education		
School/vocational education (referent)	1	1
University education and higher	1.50 (0.94, 2.42)	**1.60 (1.07, 2.31)**
Family size (Number of children in the family)		
1 child (referent)	1	1
2 children	0.69 (0.43, 1.12)	0.84 (0.57, 1.25)
>3 children	0.55 (0.27, 1.13)	0.67 (0.38, 1.19)
Family composition		
Two parent household (referent)	1	1
Single parent household	**3.00 (1.11, 8.68)**	1.43 (0.55, 3.76)
Mother's country of birth		
Australia and NZ (referent)	1	1
Asia except India	0.81 (0.39, 1.68)	0.57 (0.30, 1.08)
India	0.87 (0.41, 1.84)	**0.47 (0.24, 0.92)**
Other countries	0.61 (0.27, 1.40)	**0.38 (0.19, 0.79)**

Note: Statistical models fit to n = 641 complete cases. This model was adjusted for child age and child sex. The bold values denote the Relative Risk Ratios that are farther from the referrent (RRR=1).

[a]Results expressed as relative risk ratios (RRR) relative to free sugars >10% EER.

[b]RRR shows effect of each additional year of age.

Australian children, in the 2011–12 national survey (Australian Bureau of Statistics, 2017). The inclusion of cereal bars in this food grouping in the current analysis may account for the difference. The current data are, however, similar to the reported intake of free sugars from biscuits, cakes and pies in American 2–5-year-old children (20%) (Neri et al., 2019) and the UK 4–10-year-old children (23.5%) (Amoutzopoulos et al., 2020). In the current study Sweetened Milk Products, predominantly yoghurts, contributed a median 12% to free sugars. This is similar to the results from a survey of 5–9-year-old Portuguese children (12% from sweetened yoghurts) (Marinho et al., 2020) and 2–5-year-old American children (12.3% from sweetened milk) (Neri et al., 2019). In the present analysis, breakfast cereals contributed a median of only 0.2% to free sugars. This is considerably lower than the proportion of free sugars from ready-to-eat breakfast cereals (3.8%) by 4–8-year-old Australian children reported in the earlier survey (Australian Bureau of Statistics, 2017) however, cereal and breakfast bars were included in this food category in this survey. The current value is also much lower than that for UK 4–10-year-old children (34%) (Amoutzopoulos et al., 2020), and Portuguese 5–9-year-old children (10.3%) (Marinho et al., 2020). The current study results indicate that children are exposed to hidden free sugars in baked goods and sweetened yoghurts at an early age. Strategies could tackle the widespread marketing of seemingly healthy foods like sweetened yoghurts, by incorporating clear food labelling that discloses free sugars and highlights the potential impact on dental health (Taillie et al., 2021).

The contribution of beverages (median 6.7%) to free sugars in the current study is very low when compared with the proportion of free sugars contributed by beverages (34%) in 4–8-year-old Australian children, reported in the 2011–12 survey (Australian Bureau of Statistics, 2017). SSBs including cordials, soft drinks, frozen drinks, flavoured water and juices contributed a median 1.5% to free sugars in the present analysis. In contrast, SSBs were the leading contributors to free sugars in, 2–5-year-old children in Lebanon (36%) (Jomaa et al., 2021), Europe (51%) (Graffe et al., 2020) and the USA (20%) (Neri et al., 2019). When compared with the results from the 2011–12 National survey, the findings may suggest that there is a decline in the consumption of SSBs in Australia. It has been suggested that the public in Australia are more health conscious and therefore avoid SSB intake (Australian Bureau of Statistics, 2017). In the present study, intake from SSBs could have been under-reported by the mothers as they were aware of the upcoming dental survey. Moreover, the data from the 2011–12 National survey are more than 10 years old.

In line with the current findings, the results from a meta-analysis on SSB intake in countries with high dietary-related burden of disease showed that the SSB intake in 2–18-year-olds in Australia was the lowest in the world (Ooi et al., 2022). The policies in Australia around limiting the marketing of SSBs to children and increasing access to drinking water (Obesity Policy Coalition, 2021) may help explain the results on the low contribution of beverages to free sugars intake. Wider adoption of such strategies in other countries where SSB intake is higher may lead to significant reductions in free sugars intake. In recent years, there has been a global focus on SSB taxation as a means of reducing sugars intake. Based on the current information on the main contributors to sugars intake at age 5, targeting the intake of biscuits, cakes and sweetened milk products, especially yoghurts, through reformulation efforts, strategies to target marketing and, health education may have more impact on lowering free sugars intake. Efforts towards voluntary product reformulation have been initiated in Australia in 2020. While foods containing added sodium and saturated fat were prioritised in the first phase of this programme, data from the present analyses could contribute to underpin approaches to reformulate sources of free sugars. Data from the UK (Public Health England, 2022) on the progress of sugars reduction and product reformulation show that there was an overall 3.5% reduction in the total sugar per 100 g

(sales weighted average) in products sold between 2015 and 2020, with larger reductions in specific products like yoghurts (14%) among other foods. These data support the efficacy of reformulation programmes in lowering intake from specific food sources known to contain high free sugars.

The finding from the present study that maternal education was a significant determinant of free sugars intake within the WHO thresholds in children concurs with previous finding from a study of Lebanese children (Jomaa et al., 2021) which showed children of mothers who attained a higher level of education consumed less free sugars. These findings also align with the results from a systematic review on determinants of beverage intake, which showed that lower parental education is associated with higher intake of SSBs in children (Mazarello Paes et al., 2015; Ooi et al., 2022). The current study finding that children of mothers classified as being born in *India*, or *Other Asian Countries* were less likely to achieve the WHO recommended thresholds for intake compared with children of mothers born in Australia and New Zealand confirms the findings observed for the study cohort at aged 2 years (Devenish, Golley, et al., 2019). Cultural influences, feeding practices by mothers from different ethnic backgrounds, and a shift in dietary patterns after migration to a different country possibly explain the results of the present analysis. Furthermore, this finding from the present study aligns with the results of studies on changes in diet after migration which reported an increase in intake of SSBs, refined foods and a substantial increase in energy intake in South Asians (Holmboe-Ottesen & Wandel, 2012). An improved understanding of the ethnic and cultural factors affecting the food and drink intake by children from families who migrate from India and other Asian countries to Australia will help provide more support to such families with respect to health education and provision of healthy environments to live in.

In the present analysis, despite the finding that higher maternal education, often considered a proxy for SES, was associated with children achieving the threshold of free sugars intake, there was no difference based on the IRSAD classification. In alignment with this observation, data from the UK (Rugg-Gunn et al., 2007) show sugars intake not to vary by social groups based on income and occupation. However, several other countries do report SES differences (Devenish, Golley, et al., 2019; Dietary Guidelines for Americans, 2020; Marinho et al., 2020). The finding from the present analysis is suggestive of an intake of free sugars above the <5% threshold by all 5-year-old children independent of SES, and therefore highlights the need for an early nutrition intervention for all children.

It was found that children born into single-parent households (4.7%), were more likely to achieve the WHO recommended thresholds in the present study. This finding contrasts with earlier data from Australia, which showed being in a single-parent environment was associated with increased intake of SSB by children (Renzaho et al., 2014; te Velde et al., 2012). The Labour Force Status of Families in Australia reports a growing number of single-parent households. More than half of one-parent families (51.5%) had a youngest dependent aged 0–9 years and 72% had an employed mother at dependent age 5–9 years (Australian Bureau of Statistics, 2022). These data are suggestive of a changing population dynamic. Perhaps being in a single parent family is no longer a proxy for a lower SES (te Velde et al., 2012). Though from a small subsample, the finding from the present study is suggestive of the need to explore further about the factors that influence eating habits of children belonging to one-parent families.

4.1 | Limitations

There are several limitations to the study which are acknowledged. First, a retrospective questionnaire was used to collect dietary data, therefore recall bias cannot be ruled out (Moynihan et al., 2009; Nelson & Bingham, 1997). However, the SMILE-FFQ was previously validated as a tool to assess sugars intake against the multiple pass 24-h method with acceptable comparability (Devenish et al., 2017). Second, mothers were aware about the follow up investigations including oral examinations which were conducted as a part of the wider study. Therefore, it is possible data were subject to bias of social desirability (Radnitz & Todd, 2016) resulting in an over or underreporting of the intake of certain foods and drinks. Third, as EI could not be derived from the dietary assessment instrument, the analysis used the estimated EER of the child and not their EI to estimate the contribution of sugars to EI which will affect the accuracy of the data. The median EER was attributed to participants with missing anthropometric data (7.5%) which could have resulted in an over or underestimation of contribution of free sugars intake to EER in these participants. However, the use of EER is a recognised proxy for EI to apply in situations where EI cannot be derived (Devenish, Golley, et al., 2019) and EER was derived using well-established methods (Brooks et al., 2004; Gerrior et al., 2006; Seale, 2002). The observed attrition rates from the SMILE Cohort study are comparable with other research studies and during recruitment, participants from the socially disadvantaged areas were oversampled to address a possible loss to follow-up (Do et al., 2020). Despite originating from a single-centre cohort, these data hold national relevance, reflecting the ubiquitous presence of free sugars in foods such as cakes, biscuits, cereal bars, and sweetened yoghurts within urban food environments that children encounter across Australia.

4.2 | Future directions

The current study has shown that the intake of free sugars in this cohort study of 5-year-old children remains higher than the WHO lower threshold for the majority of children, indicating that while targeted intervention efforts to lower intake may be having a positive impact on reducing the consumption of free sugars from specific sources, for example, SSBs, sustaining and enhancing interventions that comprehensively address sugars sourced from foods perceived as healthy remain a priority, for instance, sweetened yoghurts. The

findings of the current analysis contribute to disentangling the factors that are associated with achieving recommended thresholds on sugars intake. Such information is useful in informing health promotion and public health nutrition interventions. Future research should develop and evaluate upstream interventions to lower sugars consumption provided by the hidden sugars in baked goods, sweetened milk products, and desserts. These strategies should include exploring impacts of product reformulation (Australian Institute of Health and Welfare, 2021, targeted health promotion (Food for Health Alliance, 2023) and analysing the drivers of marketing and advertising and not limit the efforts to standalone downstream approaches such as individual behaviour change (Moynihan & Miller, 2020). Qualitative research including focus group discussions with parents, especially mothers, of young immigrant children could lead to the generation of an evidence-base on the factors that inform dietary choices in this specific community.

5 | CONCLUSION

The WHO conditional recommendation to limit free sugars to below 5% Energy aims to protect dental health throughout the life course. From the current findings, it can be concluded that Australia has some way to go to reach this recommendation. Cakes, Biscuits and Cereal Bars, Sweetened Milk Products [predominantly yoghurts] and Desserts were the principal contributors to free sugars intake. The current findings would support interventions that aim to improve the healthfulness of the wider food environments, prioritise product reformulation, tackle marketing and, work with priority populations such as migrants and those with lower education or health literacy.

AUTHOR CONTRIBUTIONS

The study was conceptualized by the SMILE team: Gemma Devenish, Loc Giang Do, Diep H. Ha, Jane A. Scott, Rebecca Golley, and Lucy K. Bell. *Data collection, initial analysis, software, methodology, validation*: Gemma Devenish, Loc Giang Do, Lucy K. Bell, Rebecca Golley, Diep H. Ha, Jane A. Scott. *Funding acquisition*: Diep H. Ha, Loc Giang Do, and Jane A. Scott. *Supervision*: Paula J. Moynihan, Loc Giang Do, Lynne Giles. *Statistical analyses of the age 5 data*: Lynne Giles, Anupama Ivaturi. *Writing—original draft*: Anupama Ivaturi as a part of her PhD studies with substantial contributions from, Paula J. Moynihan, Lynne Giles, Loc Giang Do. *Writing—review and editing*: Anupama Ivaturi, Paula J. Moynihan, Loc Giang Do, Lynne Giles, Gemma Devenish, Rebecca Golley, Diep H. Ha, Lucy K. Bell, and Jane A. Scott.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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