ORIGINAL ARTICLE

Dietary intakes in children born small for gestational age and appropriate for gestational age: A longitudinal study

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Abstract

Children born small for gestational age (SGA) have an increased risk of cardiovascular disease (CVD) and associated risk factors in later life; however, little is known about their dietary intakes. The objective of this study was to assess dietary intakes in SGA and appropriate for gestational age (AGA) at 3.5, 7, and 11 years. The Auckland Birthweight Collaborative Study is a longitudinal case-control study of children born at term ($n = 871$). Children were assessed at 3.5 ($n = 550$), 7 ($n = 591$), and 11 ($n = 620$) years of age. Diet was assessed using a 24-hr record-assisted recall. Reported dietary intakes were analyzed and compared with the Australian and New Zealand Nutrient Reference Values. Compared with AGA, median energy intakes were significantly lower in SGA at 3.5 years (4.2 MJ [IQR, 3.0 to 5.8] vs. 5.4 MJ [IQR, 3.9 to 6.5]; $p < .0001$) but not at 7 and 11 years. Inadequate dietary intakes of micronutrients were more prevalent among SGA at 3.5 years and 11 years of age. A large proportion of SGA and AGA children consumed more than the recommended amounts of saturated fats, sugars, and sodium. There was no association of dietary intake and socio-demographic factors. This study reveals that dietary intake in 3.5-year-old children born SGA is lower in energy and a variety of micronutrients compared with dietary intake in AGA. These intakes may however be appropriate given their BMI z-scores. High intakes of sodium, saturated fat, and sugars are a concern for all children in this cohort.

KEYWORDS

children, dietary intake, longitudinal study, macronutrient, micronutrient, small for gestational age

1 | INTRODUCTION

Optimal nutrition during childhood is important for normal growth, brain development, and health. The food environment for children today is challenging with easy access to cheap energy rich foods that are often micronutrient-poor (Swinburn, Caterson, Seidell, & James, 2004).

In New Zealand, the rates of obesity have increased remarkably in recent years, and currently, 30% of children are overweight and obese (Ministry of Health, 2015). The National Children's Nutrition Survey found that children aged over 5 years consume excess amounts of fats, sugars, and fast foods (Ministry of Health, 2003). According to a recent review, these dietary factors not only increase the risk of obesity but also of cardiovascular disease (CVD) and are also associated with increased risk of micronutrient deficiencies (Lachat et al., 2012).

Children born small for gestational age (SGA) have been reported to have an increased risk of CVD and its risk factors, including the Metabolic Syndrome (MetS) in comparison to those born appropriate for gestational age (AGA) (Saenger, Czernichow, Hughes, & Reiter, 2007). The highest risk appears to be in those who gain the most weight, particularly in infancy or childhood (Wells, 2011; Stettler, Kumanyika, Katz, Zemel, & Stallings, 2003; Dunger, Salgin, & Ong, 2007).

The strong association between diet and the risk of CVD and MetS emphasizes the need to investigate longitudinal measures of dietary intakes in children born SGA along with measures of childhood growth. Previous studies have shown that tracking of dietary intake begins as young as 3–4 years (Singer et al., 1995; Fisk et al., 2011). Currently, there is lack of longitudinal data comparing age-related changes on dietary intakes in SGA and AGA and in boys and girls. The Auckland Birthweight Collaborative (ABC) Study has a rich data set of longitudinal data, including nutrient intakes from a birth cohort of SGA and AGA, as well as information on growth and demographic

[Correction added on 10 November 2017, after Online and Print publication: Dr. Pushpa Wati was missed from the list of authors and has been added in this version. Her contribution is updated in the Contributions section.]

variables, which provides an opportunity to study age-related changes in nutrient intakes. The aim of this study is to describe the dietary intakes of SGA and AGA children who participated in the ABC study at ages 3.5, 7, and 11 years by examining (a) median daily dietary intakes of micronutrients and macronutrients and the percentage contribution of macronutrients to energy and (b) the proportion of children with median daily intakes less than the nutrient reference values (NRVs) and above the acceptable macronutrient distribution ranges (AMDRs).

2 | METHODS

2.1 | Setting and participants

Data for this study were obtained from the ABC Study, an on-going prospective cohort study investigating the factors influencing growth, development, and health outcomes in SGA and AGA children. Background information about the study design, subjects, and the recruitment procedures has been described in a previous publication (Thompson et al., 2001). Briefly, infants born between October 16, 1995 and August 12, 1996 to mothers who resided in the Waitemata Health or Auckland Healthcare regions were eligible for inclusion; and from August 12, 1996 to November 30, 1997, babies born in the Auckland Healthcare region were eligible to participate. All children were born at ≥ 37 weeks' gestation. Infants were excluded from participation if they were from multiple births, had a congenital anomaly, or were delivered at home. At birth, all SGA ($< 10\%$ percentile for gestational age) children were selected and a random sample of children born AGA as controls. Children were initially assessed at birth (Phase 1; 1995 to 1997) and during subsequent follow-ups at 12 months (Phase 2; 1996 to 1998), 3.5 years (Phase 3; 1999 to 2001), and 7 years (Phase 4; 2002 to 2005) and most recently at 11 years (Phase 5; 2008 to 2010). Parents and guardians were required to sign a written consent form to allow participation of their children in the study at all time points. Assent was also obtained from each child at 11 years. Ethics approval for each phase of this study was obtained from the Northern Regional Ethics Committee.

2.2 | Socio-demographic information

Socio-demographic characteristics, including socioeconomic and life-style information about the child and the family were collected through an interviewer-administered questionnaire.

2.3 | Weight and height

From Phases 3 to 5, children and their parents or guardians were invited to the clinic at Children's Research Centre for assessment. At each visit, anthropometric measurements were performed for each child by trained staff using standardized procedures and calibrated equipment. Body weight was recorded to the nearest 0.1 kg using calibrated portable electronic scale (Tanita, Tokyo, Japan), with children barefoot and lightly dressed. Height was measured three times to the nearest millimeter, also without shoes, using a portable stadiometer fixed to the wall (Pharmacia Upjohn, London, UK). SGA was defined as equal to or below the sex-specific 10th percentile for gestational age in the New Zealand population, and AGA babies weighed more than the 10th percentile for gestational age at birth (Thompson et al., 2001). BMI z-scores were calculated using published norms (Cole, 1990).

2.4 | Assessment of children's diet

A 24-hr food record-assisted recall (24-hr RAR) was used to assess dietary intake. Before the assessment, parents/guardians were mailed a 24-hr food diary, in which they recorded all the food and drinks their child consumed in the day prior to their visit. Instructions were provided to the parents to assist with the accurate recording of all food and drinks consumed by the child. To improve accuracy of the diet record, all information was also checked by trained staff for a full description of the type and amount of food eaten, including brand name, where/when it was eaten, portion size, and details of any leftovers. Standard household measures and volumetric aids were used to check portion sizes. When portion sizes were not stated, an appropriate amount based on the child's age was estimated. Where necessary, information on recipes for home-cooked meals was also obtained from parents or caregivers. For these recipes, ingredients were entered individually for the whole dish, the number of servings it made, and the estimated yield. The food records were analyzed using Foodworks Professional software 2007 and 2009 edition with New Zealand FOODfiles 2004 as the database (Xyris Software, Australia), which contains a comprehensive list of foods commonly eaten in Australia and New Zealand.

2.5 | Statistical methods

All statistical analyses were carried out using SAS (version 9.3, SAS Institute Inc, Cary, NC). A significance level of $p < .05$ was used to determine statistical significance. Nutrient data are not normally

Key messages

- Children born SGA have lower dietary energy and micronutrient intakes at 3.5 years and lower dietary micronutrient intakes at 11 years compared with children born AGA.
- Children born SGA and AGA children have an intake of sodium, saturated fats, and sugars significantly above the recommended dietary intakes for age.
- Children born SGA remain shorter, lighter, and have lower BMI z-scores compared with children born AGA from ages 3.5 to 11 years.

distributed, so they have been log-transformed to determine outliers. Because misreporting has been recognized as a major bias in dietary surveys, underreporters and over-reporters of energy and nutrients were removed (Livingstone, Robson, & Wallace, 2004). We used standard methodology developed by Tukey to exclude reported intakes above or below the upper and lower limits (Tukey, 1977). After removing data as described, 11% of 3.5-year-olds, 5% of 7-year-olds, and 10% of 11-year-olds were excluded from the analysis. This resulted in data for 456 subjects at 3.5 years, 556 at 7 years, and 568 at 11 years.

Nonparametric tests (Wilcoxon signed rank) were used to compare distribution of nutrient intakes in SGA and AGA. Energy intakes were compared with the estimated energy requirements (EER). Basal metabolic rate (BMR) was calculated using the Schofield equation with the group mean weight, height, and corresponding age and gender (Schofield, 1985). Moderate level of physical activity (1.8) was used to calculate EER. To determine the adequacy of the macronutrients and micronutrients intakes, the medians were evaluated against the NRVs for Australia and New Zealand (NHMRC, 2006). The percentage of SGA and AGA below NRVs was compared using Pearson's χ^2 test. To assess the macronutrient intakes, we examined the energy intakes for macronutrients relative to AMDRs (for adolescents and adults) defined in the NRVs (NHMRC, 2006). They are expressed as a percentage of total energy intakes. Intakes reported were above 15% of energy for protein, 30% of energy for total fat, 11% of energy for saturated fatty acids (SFA), and above 55% of energy for carbohydrates (CHO). The following dietary intakes were reported, where CHO ≥ 300 g, total sugars ≥ 60 g, total fat ≥ 65 g, SFAs ≥ 20 g, and cholesterol ≥ 300 mg. For micronutrients, sodium and dietary fiber, intakes were compared with age- and gender-specific adequate intake (AI) cut-offs to estimate the proportion with inadequate intakes (NHMRC, 2006).

3 | RESULTS

3.1 | Characteristics of subjects

The study consisted of 1,714 children at birth of which 871 were identified as being of European descent, of whom 3.5 (44%) were SGA and 486 (56%) were AGA (Figure 1). At Phase 3, 550 (63%) attended the assessment. 24-hr RAR was completed from 514 children (59%) at Phase 3. Subsequently, at Phases 4 and 5, 573 (66%) and 613 (70%) were completed. Nonparticipants were residing overseas, out of the local area, or lost to follow-up.

The mean $\pm$ standard deviation (SD) of weight, height, and BMI z-score in SGA and AGA, by age, is shown in Table 1. The means of all these anthropometric measures were significantly higher in AGA than SGA at all ages. All groups had a mean BMI z-score greater than zero, except for SGA at 3.5 years. BMI z-scores increased gradually with age.

Reported dietary intakes of total energy, macronutrients, and dietary fiber according to age and SGA status are summarized in Table 2. The median intake of energy, CHO, total sugars, dietary fiber, protein, total fats, SFA, monounsaturated fatty acids, polyunsaturated

FIGURE 1 Flow diagram of enrolment and retention of participants in the Auckland Birthweight Collaborative Study

fatty acids (PUFA), and cholesterol were statistically significantly lower in SGA compared with AGA at 3.5 years. There were increases in energy and macronutrient intakes between 3.5 and 7 years of age in both the SGA and AGA groups. By 7 years, there was no statistically significant difference in energy and macronutrient intakes.

The percentage contributions of macronutrients to energy are shown in Table 3. Carbohydrates contributed between 51% and 55% of energy intake at all ages, whereas contributions from protein and total fat were between 14% to 16% and 29% to 32% of energy, respectively. A significant number of children consumed total fats and total sugars in excess of the AMDR at all ages. All children, at all ages, had daily intake of energy from SFAs above 10%. PUFA contributed 11% to 13% of total energy and were $>10\%$ of total energy intake for a large proportion of children at all ages. The proportion of children with cholesterol intake greater than 300 mg/d also increased with age.

The estimated percentage of inadequate and adequate intakes of dietary fiber, sodium, and micronutrients are shown in Tables 3 and 4. Compared with the AGA group, SGA did not achieve the estimate average requirement (EAR) for a variety of micronutrients at 3.5 years. At 7 and 11 years, a significant proportion of both SGA and AGA had inadequate intakes of selenium, potassium, and folate. At 11 years, the proportion of inadequate intakes of folate, vitamin A, riboflavin, and selenium was higher in SGA compared with AGA. There was also an increase in the prevalence of inadequate calcium intakes between 7 and 11 years both in SGA and AGA. In almost all children, sodium intakes exceeded the respective upper limits (UL). Overall, more than half the children did not meet the recommended intake of dietary fiber.

TABLE 1 Height, weight, and BMI z-score in children born SGA and AGA by age, ABC Study

	3.5 years			7 years			11 years		
	SGA	AGA	<i>p</i>	SGA	AGA	<i>p</i>	SGA	AGA	<i>p</i>
N (%)	189 (41)	267 (59)		230 (41)	334 (59)		255 (41)	354 (59)	
Weight (kg), mean ± SD	15.9 ± 2.1	17.5 ± 2.3	<.0001	24.5 ± 4.9	26.8 ± 5.1	<.0001	40.3 ± 10.6	43.9 ± 10.3	<.0001
Height (cm), mean ± SD	100.1 ± 4.8	102.8 ± 3.8	<.0001	122.7 ± 5.8	125.8 ± 5.3	<.0001	147.0 ± 7.4	150.8 ± 7.4	<.0001
BMI z-score, mean ± SD	-0.1 ± 0.8	0.3 ± 0.7	<.0001	0.1 ± 1.1	0.5 ± 0.9	<.0001	0.2 ± 1.2	0.5 ± 1.1	.0027

AGA = appropriate for gestational age; SGA = small for gestational age; BMI = body mass index; ABC = Auckland Birthweight Collaborative; SD = standard deviation.

A number of factors (including sex, centile, gravida, occupation, age at pregnancy, and smoking during pregnancy, marital status, and socioeconomic status) were investigated in relation to risk of nutrient inadequacy, but no consistent relationships were found.

4 | DISCUSSION

To our knowledge, this is the first longitudinal study to compare the dietary nutrient intakes of SGA and AGA children. We have demonstrated children born SGA have lower energy and micronutrient intakes at 3.5 years compared with children born AGA and are less likely to meet the NRVs for some micronutrients at 11 years. Children born SGA remained shorter, lighter, and had lower BMI z-scores compared with AGA children from ages 3.5 to 11 years. Both SGA and AGA children had a reported dietary intake of sodium, saturated fats and sugars above recommended levels across all ages.

Small for gestational age children had lower energy intakes at 3.5 years, which commensurate with their BMI z-scores, which were significantly lower than the mean BMI z-score of +0.3 for AGA children. Early catch-up growth after SGA birth is a risk factor for insulin resistance in childhood and CVD in adult life (Saenger et al., 2007). Therefore, too much weight gain in early childhood should be prevented in infants born SGA (Cho & Suh, 2016). The SGA children in this study may be protected from the adverse effects of early catch-up growth as the findings from this study demonstrate dietary energy and protein intakes at 3.5 years, which are proportionate for their size. At 7 and 11 years of age, median dietary energy intakes did not differ significantly between AGA and SGA. However, a higher proportion (42%) exceeded the EER at 7 years compared with 12–18% at 11 years.

A substantial number of SGA and AGA children also consumed inadequate amounts of dietary fiber. This is consistent with the results from previous published national data (Ministry Of Health, 2003). Previous analyses of the ABC Study, dietary data have also demonstrated that children consumed inadequate amounts of fruits and vegetables at 3.5 years, which are the major sources of dietary fiber in New Zealand (Theodore et al., 2006).

Micronutrients play a major role in growth and development in children. Our results show that a large percentage of children did not meet the NRVs for a range of micronutrients at 3.5 years. Our findings show that 42% of 11-year-old SGA children had intakes below the NRVs compared with 33% AGA for vitamin A, higher than the rates reported nationally (10% in 5- to 14-year-olds). Furthermore, a

significant proportion of SGA children did not meet the NRVs for riboflavin, folate, and selenium at age 11 years. Folate is important for growth, and its intake was relatively low in approximately half of 11-year-olds. This is again higher than the rates reported nationally (37%) (Ministry Of Health, 2003). In New Zealand, food manufacturers can voluntarily add folate to breads, breakfast cereals, juices; however, not many foods are fortified, and a significant percentage of older children miss breakfast (Utter, Scragg, Mhurchu, & Schaaf, 2007), which could explain why many children are not meeting their requirements. Calcium deficiency can have major health implications as calcium is important for growth and attainment of peak bone mass (Ondrak & Morgan, 2007). Our findings show that approximately 60% of 11-year-olds (64% SGA, 57% AGA; $p < .05$) had intakes below the EARs. This rate is comparable with those reported nationally (68% for children aged 5 to 14 years) and confirms that poor dietary calcium intake is an issue in New Zealand children (Ministry Of Health, 2003). Furthermore, a significant proportion of children did not meet the requirements for selenium at 11 years, most likely attributable to poor selenium content of the New Zealand diet, as reported elsewhere (Thomson et al., 2007).

The consequence of a higher proportion of the SGA children not meeting the NRVs for a number of the micronutrients such as riboflavin, folate, selenium, calcium, and vitamin A is not known. SGA children were still smaller than the AGA children at 7 and 11 years despite there being no significant differences in total dietary energy or protein intake. This suggests that the nutrient density of their diet is lower compared with the AGA children. The long-term consequences of this on the health and development of these children is unknown, and further investigation of this cohort is warranted.

There are no recommended acceptable macronutrient intake distribution ranges for young children. In this study, we compared macronutrient intakes to the AMDR for adolescents and adults. Although this may have no immediate health significance in childhood, long-term exposure to diets that are high in sugars and saturated fats may increase the risk of chronic disease in adult life (Dunger et al., 2007; Fisk et al., 2011; Singer et al., 1995). A significant number of children had intakes of sugar >60 g per day and saturated fat intakes of >11% per day. For sodium, almost all children exceeded the AI for their respective ages. Follow-ups at 7 and 11 years showed all children exceeded the UL. This amount could be even higher because discretionary use of salt in cooking and at the table was not captured in the 24-hr RAR. A high salt intake is associated with high blood pressure in children (He, Marrero, & Macgregor, 2007), which is linked with

TABLE 2 Reported median (25th, 75th percentile) intakes of total energy, macronutrients, and dietary fiber by SGA status and age, ABC Study

	3.5 years (N = 456)			7 years (N = 564)			11 years (N = 609)		
	SGA	AGA	p	SGA	AGA	p	SGA	AGA	p
Energy (MJ)	4.241 (3.008, 5.838)	5.360 (3.905, 6.518)	<.0001	7.480 (5.931, 9.144)	7.386 (6.242, 8.770)	.904	7.255 (5.719, 8.966)	7.420 (6.020, 9.404)	.127
Carbohydrate (g)	140 (100, 185)	170 (122, 219)	<.0001	246 (190, 299)	238 (194, 294)	.694	225 (179, 283)	221 (184, 272)	.522
Total sugars (g)	78 (48, 112)	86 (59, 116)	.0287	116 (85, 151)	113 (87, 151)	.870	101 (72, 149)	102 (76, 133)	.800
Protein (g)	35 (22, 50)	45 (31, 60)	<.0001	63 (49, 77)	62 (50, 79)	.726	66 (48, 87)	71 (52, 93)	.094
Total fat (g)	33 (24, 48)	42 (31, 54)	<.0001	59 (45, 73)	58 (46, 75)	.750	60 (46, 84)	65 (47, 84)	.154
Saturated fat (g)	16 (11, 23)	20 (14, 26)	<.0001	25 (19, 34)	26 (19, 34)	.948	26 (19, 36)	26 (19, 36)	.488
Monounsaturated fat (g)	11 (7, 15)	13 (9, 18)	.0001	19 (15, 24)	19 (14, 25)	.945	19 (14, 28)	21 (16, 28)	.057
Polysaturated fat (g)	3 (2, 5)	4 (3, 6)	.0016	6 (5, 9)	7 (5, 10)	.795	7 (5, 9)	7 (5, 11)	.084
Cholesterol (mg)	89 (62, 134)	118 (75, 161)	.0018	156 (106, 231)	155 (104, 224)	.983	179 (114, 274)	187 (127, 284)	.203
Dietary fiber (g)	9 (6, 13)	10 (7, 15)	.0006	16 (13, 21)	16 (12, 21)	.588	16 (12, 21)	17 (12, 23)	.227

AGA = appropriate for gestational age; SGA = small for gestational age; ABC = Auckland Birthweight Collaborative.

stroke and coronary heart disease in adults. Furthermore, between 46% to 61% of children consumed fat in excess of 30% of total energy, and all children had intakes of saturated fat >11% of total energy. In addition to this, as many as 92% of SGA and AGA children consumed more than the World Health Organization recommendations for free sugars (10% of total energy intake; World Health Organisation, 2015). High consumption of sugar sweetened beverages is associated with increases of childhood obesity, a major risk factor for Type 2 diabetes and CVD (Davis et al., 2007; Ludwig, Peterson, & Gortmaker, 2001). The SGA children in this cohort did not demonstrate a significant rate of postnatal catch-up growth, but they may still have increased susceptibility to postnatal fat deposition, and high dietary intakes of saturated fat, sugar, and salt may predispose them to long-term health risks (Ibanez et al. 2006).

This study has several strengths, its prospective design, relatively large sample size, reasonable retention rates (59% to 70%), and our ability to assess dietary intakes at different stages from preschool to preteen. The response rates are unlikely to cause any systematic bias because the percentage of SGA and AGA children remained consistent at all phases of the study at 41% and 59%, respectively. Changes in eating behavior (Miller et al. 1991) and variations in nutrient intakes or incorrect estimation of physical activity levels (PAL) are causes of discrepancies when estimating energy intake. New Zealand children are generally active, so we used a PAL of 1.8 to calculate BMR, which is considered appropriate for this age group (Ekelund et al., 2001). In the present study, dietary information was collected for only 1 day, which might not be adequate at an individual level because nutrient intakes vary significantly in children and usually twice as much as in adults (Nelson, Black, Morris, & Cole, 1989). The data were also adjusted to remove underreporting and over-reporting, and up to 11% of the data was removed at each age. Previous studies that measured energy intake using 8-day diet record and measured energy expenditure using doubly labeled water show similar rates of underreporting in children (17% to 33%) (Champagne, Baker, Delany, Harsha, & Bray, 1998). A single 24-hr RAR may not reflect individual usual intake; however, the sample size was large enough to estimate intakes at a group level (Livingstone & Robson, 2000). The parents or guardians of the children recorded the 24-hr dietary intake and provided at interview further information on quantities of food eaten. Although this is appropriate for young children who are not capable of recalling dietary information, this has limitations in that inaccurate reporting by the proxy respondent is possible (Champagne et al., 1998). Reporting accuracy is relatively good in children especially if assisted by parents and caregivers (Johnson, Driscoll, & Goran, 1996). Older children can also accurately estimate their intakes because they are more aware of the foods they eat and can clearly remember the foods items they have consumed (Baranowski & Domel, 1994). Lastly, it needs to be noted that data were only obtained from children of mothers identified as being New Zealand European; therefore, findings of this study may not be generalizable to all New Zealand children. Despite these limitations, we believe that the strength of this study lies in the longitudinal collection of data and the repeated measurement of dietary intake at three significant time points in childhood. Long-term, this

TABLE 3 Median (25th, 75th percentile) percent contribution of macronutrients to energy and percentages exceeding the NRVs and AMDRs by SGA status and age, ABC Study

	3.5 years (N = 456)			7 years (N = 564)			11 years (N = 609)		
	SGA	AGA	p	SGA	AGA	p	SGA	AGA	p
Energy									
EER (MJ)	M = 6.65; F = 6.14	M = 6.65; F = 6.14	<.0001	M = 8.25; F = 7.55	M = 8.25; F = 7.55		M = 10.65; F = 9.41	M = 10.65; F = 9.41	
>EER	17%	30%	.0010	42%	41%	.758	12%	18%	.128
Carbohydrate (g)									
% of energy	53 (48, 60)	53 (48, 58)	.4004	56 (50, 61)	55 (50, 61)	.566	52 (45, 58)	51 (46, 58)	.869
>55% of energy	44%	36%	.1148	54%	53%	.899	38%	34%	.425
Total sugars (g)									
>60 g	62%	73%	.0180	93%	92%	.606	82%	87%	.160
Protein (g)									
% of energy	14 (12, 16)	15 (13, 17)	.0143	14 (12, 16)	14 (12, 17)	.181	16 (12, 19)	16 (13, 19)	.902
<15% of energy	63%	57%	.2027	63%	55%	0.074	46%	40%	0.170
EAR	12	12		16	16		M = 31; F = 24	M = 31; F = 24	
<EAR	1%	1%	.5710	0%	0%		1%	2%	.462
Total fat (g)									
% of energy	31 (25, 36)	32 (26, 36)	.4910	30 (25, 34)	29 (25, 36)	.839	32 (26, 37)	32 (27, 37)	.896
>30% of energy	55%	58%	.5647	49%	46%	.499	61%	58%	.390
Saturated fat (g)									
% of energy	52 (48, 57)	53 (49, 58)	.1296	50 (44, 54)	50 (45, 54)	.538	50 (44, 54)	49(44, 54)	.452
>11% of energy	100%	100%		100%	100%		100%	100%	
Monounsaturated fat (g)									
% of energy	36 (33, 39)	35 (32, 38)	.0849	37 (34, 40)	36 (34, 39)	.128	37 (34, 41)	38 (34, 40)	.962
<20% of energy	0%	0%		0%	0%		0%	0%	
Polysaturated fat (g)									
% of energy	11 (9, 15)	11 (8, 15)	.2645	13 (10, 16)	13 (10, 17)	.626	13 (10, 17)	13 (10, 17)	.435
>10% of energy	62%	60%	.6263	76%	77%	.803	73%	75%	.608
Cholesterol (mg)									
>300 mg	4%	5%	.646	12%	15%	0.307	22%	24%	.731
Dietary fiber (g)									
AI (g)	14	14		18	18		M = 24; F = 20	M = 24; F = 20	
<AI	81%	73%	.048	59%	58%	.866	78%	74%	.332

AI = adequate intake; AGA = appropriate for gestational age; EAR = estimated average requirement ; EER = estimated energy requirement; SGA = small for gestational age; NRVs = nutrient reference values; AMDRs = acceptable macronutrient distribution ranges; ABC = Auckland Birthweight Collaborative.

TABLE 4 Reported median (25th, 75th percentile) and percentage below the NRVs for micronutrients, by SGA status and age, ABC Study

	3.5 years			7 years			11 years		
	SGA	AGA	p	SGA	AGA	p	SGA	AGA	p
Thiamin (mg)	0.8 (0.5, 1.3)	1.0 (0.7, 1.5)	.0008	1.2 (0.8, 1.7)	1.3 (0.9, 1.9)	.224	1.1 (0.8, 1.6)	1.2 (0.8, 1.8)	.095
EAR (mg)	0.4	0.4		0.5	0.5		0.7	0.7	
<EAR	16%	5%	<.0001	4%	2%	.267	18%	17%	.767
Riboflavin (mg)	1.0 (0.6, 1.7)	1.3 (0.8, 1.9)	.001	1.5 (1.1, 2.1)	1.6 (1.1, 2.2)	.0219	1.4 (0.9, 2.0)	1.6 (1.1, 2.2)	.005
EAR (mg)	0.4	0.4		0.5	0.5		0.8	0.8	
<EAR	9%	3%	.0067	2%	1%	.284	17%	9%	.005
Niacin equivalent (mg)	13.6 (9.0, 22.2)	19.0 (12.5, 23.2)	.0002	25.1 (19.0, 31.7)	24.3 (19.3, 32.4)	.787	26.7 (19.8, 35.3)	27.6 (21.3, 35.8)	.252
EAR (mg)	5.0	5.0		6.0	6.0		9.0	9.0	
<EAR	3%	0%	.0117	0%	0%		0%	0.6%	.234
Vit B ₁₂ (µg)	1.7 (1.1, 2.8)	2.2 (1.4, 3.3)	.002	2.7 (1.7, 4.2)	2.6 (1.7, 4.2)	.575	2.6 (1.6, 4.1)	2.7 (1.8, 4.3)	.445
EAR (µg)	0.7	0.7		1.0	1.0		1.5	1.5	
<EAR	9%	6%	.1965	5%	8%	.256	21%	19%	.586
Vit B ₁₂ (µg)	1.7 (1.1, 2.8)	2.2 (1.4, 3.3)	.002	2.7 (1.7, 4.2)	2.6 (1.7, 4.2)	.575	2.6 (1.6, 4.1)	2.7 (1.8, 4.3)	.445
EAR (µg)	0.7	0.7		1.0	1.0		1.5	1.5	
<EAR	9%	6%	.1965	5%	8%	.256	21%	19%	.586
Folate (µg DFE/d)	113.0 (76.6, 177.0)	139.6 (98.4, 201.4)	.003	216.6 (158.9, 315.4)	238.1 (169.9, 363.4)	.101	217.3 (157.0, 337.9)	275.3 (181.8, 393.9)	.0005
EAR (µg)	120	120		160	160		250	250	
<EAR	52%	37%	.0028	25%	21%	.272	56%	45%	.0119
Vit a (µg retinol activity q/d)	354.2 (206.4, 550.9)	437.3 (265.7, 675.9)	.0003	523.6 (337.5, 909.4)	591.9 (357.3, 915.5)	.538	493.0 (340.7, 949.4)	607.3 (365.1, 984.8)	.0938
EAR (µg)	210	210		275	275		M = 445; F = 420	M = 445; F = 420	
<EAR	26%	13%	<.0001	16%	16%	.853	42%	33%	.0334
Vit C (mg)	65.6 (35.6, 121.1)	77.5 (39.2, 142.5)	.096	100.8 (53.1, 188.3)	111.9 (55.0, 186.6)	.618	93.0 (50.8, 163.8)	86.5 (45.2, 140.2)	.195
EAR (mg)	25	25		25	25		28	28	
<EAR	18%	11%	.0523	6%	9%	.315	13%	14%	.703
Vit D (µg)	0.7 (0.3, 1.6)	0.8 (0.4, 1.6)	.112	0.7 (0.3, 1.5)	0.9 (0.3, 1.9)	.134	0.9 (0.3, 1.7)	1.0 (0.4, 2.1)	.047
AI (µg)	5.0	5.0		5.0	5.0		5.0	5.0	
<AI	97%	95%	.3296	97%	95%	.193	95%	93%	.3845
Sodium (mg)	1271.3 (825.8, 1804.5)	1571.7 (1051.0, 2060.5)	<.0001	2028.3 (1544.3, 2716.8)	2147.1 (1543.8, 2775.2)	.420	2299.2 (1654.3, 2922.7)	2254.6 (1702.9, 3016.5)	.8804
AI (mg)	200–400	200–400		300–600	300–600		400–800	400–800	
>AI	100%	99%	.5145	100%	100%		98%	99%	.1135
Potassium (mg)	1509.4 (902.2, 2149.1)	1848.4 (1187.7, 2406.4)	.0003	2344.2 (1763.3, 3036.9)	2416.1 (1873.9, 3056.5)	.352	2510.1 (1859.5, 3156.3)	2578.3 (1893.9, 3290.5)	.5052
AI (mg)	2000	2000		2300	2300		M = 3000; F = 2500	M = 3000; F = 2500	

(Continues)

TABLE 4 (Continued)

	3.5 years			7 years			11 years		
	SGA	AGA	p	SGA	AGA	p	SGA	AGA	p
<AI	69%	57%	.0107	47%	44%	.448	58%	60%	.6067
Magnesium (mg)	139.1(82.8, 201.6)	164.7 (117.8, 216.6)	.0002	219.7 (165.0, 272.8)	222.0 (178.2, 279.1)	.368	219.3 (167.8, 283.1)	233.9 (178.6, 295.4)	.0675
EAR (mg)	65	65		110	110		200	200	
<EAR	14%	2%	<.0001	2%	3%	.835	40%	35%	.2553
Calcium (mg)	460.0 (281.0, 695.3)	607.6 (383.3, 867.8)	.0001	729.8 (494.0, 980.8)	726.3 (531.5, 1006.0)	.448	628.2 (456.3, 986.9)	731.3 (498.5, 1054.6)	.023
EAR (mg)	360	360		520	520		800	800	
<EAR	38%	22%	<.0001	28%	24%	.320	64%	57%	.078
Phosphorus (mg)	647.1 (429.5, 980.8)	852.4 (605.0, 1132.0)	<.0001	1111.6 (889.3, 1381.9)	1129.4 (882.5, 1423.9)	.518	1148.8 (866.1, 1497.6)	1220.7 (934.9, 1615.1)	.053
EAR (mg)	380	380		405	405		1055	1055	
<EAR	18%	7%	.0010	0%	0%		42%	36%	.126
Iron (mg)	5.2 (3.4, 7.9)	6.5 (4.6, 8.9)	.0005	9.7 (7.4, 12.0)	9.6 (7.2, 12.1)	.801	10.1 (7.7, 13.1)	10.4 (8.0, 14.0)	.184
EAR (mg)	4.0	4.0		4.0	4.0		6.0	6.0	
<EAR	34%	18%	<.0001	0.9%	1.3%	.680	12%	12%	.932
Zinc (mg)	4.3 (2.8, 6.7)	5.8 (3.8, 7.7)	<.0001	7.9 (6.2, 10.7)	7.8 (6.3, 10.3)	.680	8.5 (6.2, 11.3)	9.0 (6.5, 11.9)	.224
EAR (mg)	2.5	2.5		3.0	3.0		5.0	5.0	
<EAR	18%	7%	<.0001	0.9%	0.3%	.362	13%	10%	.224
Manganese (µg)	1436.0 (828.3, 2065.2)	1699.2 (1129.5, 2340.7)	.0003	2709.6 (1965.3, 3625.0)	2641.6 (2086.2, 3613.9)	.880	2721.4 (2003.7, 3668.2)	2840.7 (2104.8, 3905.1)	.200
AI (µg)	2000	2000		2500	2500		M = 3000; F = 2500	M = 3000; F = 2500	
<AI	72%	63%	.0330	42%	45%	.583	48%	47%	.823
Copper (mg)	0.6 (0.4, 0.9)	0.7 (0.5, 1.0)	.0031	0.9 (0.7, 1.2)	0.9 (0.7, 1.2)	.648	1.0 (0.8, 1.3)	1.0 (0.8, 1.3)	.171
AI (mg)	0.7	0.7		1.0	1.0		M = 1.3; F = 1.1	M = 1.3; F = 1.1	
<AI	66%	52%	.0024	57%	57%	.939	65%	66%	.823
Selenium (µg)	16.0 (9.2, 24.6)	20.0 (12.5, 31.1)	.0002	25.6 (17.8, 41.3)	7.0 (18.5, 41.1)	.504	29.4 (19.5, 45.1)	33.6 (22.7, 52.4)	.006
EAR (µg)	20	20		25	25		40	40	
<EAR	63%	51%	.0125	47%	45%	.616	69%	60%	.048

AI = adequate intake; AGA = appropriate for gestational age; EAR = estimated average requirement; SGA = small for gestational age; ABC = Auckland Birthweight Collaborative.

study could address specific research questions in relation to dietary exposures in childhood and health outcomes for children born SGA.

5 | CONCLUSION

This study reveals that diets in 3.5-year-old children born SGA are lower in energy and a variety of micronutrients compared with intakes in AGA. These intakes may however be appropriate given their BMI z-scores. At 11 years, a significant proportion of SGA children who had high intakes of sodium, saturated fat, and sugars are a concern for all children in this cohort. The long-term effects of sub-optimal dietary intakes in these children on differential long-term health outcomes remain to be seen.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

JT, EM, CW, RM, and KW were responsible for the design of the study, CW and JT were involved in the conduct of the research, and PW, CW, and JT were involved in the analysis of the data. PW analysed the dietary intake data. PW, CW, and JT wrote the original draft and EM, RM, and KW contributed to further interpretation of the data and editing of the manuscript. JT has primary responsibility for the final content.

REFERENCES

- Baranowski, T., & Domel, S. B. (1994). A cognitive model of children's reporting of food intake. *American Journal of Clinical Nutrition*, 59, 212S–217S.
- Champagne, C. M., Baker, N. B., Delany, J. P., Harsha, D. W., & Bray, G. A. (1998). Assessment of energy intake underreporting by doubly labelled water and observations on reported nutrient intakes in children. *Journal of the American Dietetic Association*, 98, 426–433.
- Cho, W. K., & Suh, B. K. (2016). Catch-up growth and catch-up fat in children born small for gestational age. *Korean Journal of Pediatrics*, 59, 1–7.
- Cole, T. J. (1990). The LMS method for constructing normalized growth standards. *European Journal of Clinical Nutrition*, 44, 45–60.
- Davis, J. N., Alexander, K. E., Ventura, E. E., Kelly, L. A., Lane, C. J., Byrd-Williams, C. E., ... Goran, M. I. (2007). Associations of dietary sugar and glycemic index with adiposity and insulin dynamics in overweight Latino youth. *American Journal of Clinical Nutrition*, 86, 1331–1338.
- Dunger, D. B., Salgin, B., & Ong, K. K. (2007). Session 7: Early nutrition and later health early developmental pathways of obesity and diabetes risk. *Proceedings of the Nutrition Society*, 66, 451–457.
- Ekelund, U., Sjostrom, M., Yngve, A., Poortvliet, E., Nilsson, A., Froberg, K., ... Westerterp, K. (2001). Physical activity assessed by activity monitor and doubly labelled water in children. *Medicine and Science in Sports and Exercise*, 33, 275–281.
- Fisk, C. M., Crozier, S. R., Inskip, H. M., Godfrey, K. M., Cooper, C., Robinson, S. M., & Southampton Women's Survey Study, Group (2011). Influences on the quality of young children's diets: The importance of maternal food choices. *British Journal of Nutrition*, 105, 287–296.
- He, F. J., Marrero, N. M., & Macgregor, G. A. (2007). Salt and blood pressure in children and adolescents. *Journal of Human Hypertension*, 22, 4–11.
- Ibanez, L., Ong, K., Dunger, D. B., & de Zegher, F. (2006). Early development of adiposity and insulin resistance after catch-up weight gain in small-for gestational-age children. *Journal of Clinical Endocrinology and Metabolism*, 91, 2153–2158.
- Johnson, R. K., Driscoll, P., & Goran, M. I. (1996). Comparison of multiple-pass 24-hour recall estimates of energy intake with total energy expenditure determined by the doubly labeled water method in young children. *Journal of the American Dietetic Association*, 96, 1140–1144.
- Lachat, C., Nago, E., Verstraeten, R., Roberfroid, D., Van Camp, J., & Kolsteren, P. (2012). Eating out of home and its association with dietary intake: A systematic review of the evidence. *Obesity Reviews*, 13, 329–346.
- Livingstone, M. B. E., & Robson, P. J. (2000). Measurement of dietary intake in children. *Proceedings of the Nutrition Society*, 59, 279–293.
- Livingstone, M. B. E., Robson, P. J., & Wallace, J. M. W. (2004). Issues in dietary intake assessment of children and adolescents. *British Journal of Nutrition*, 92, S213–S222.
- Ludwig, D. S., Peterson, K. E., & Gortmaker, S. L. (2001). Relation between consumption of sugar-sweetened drinks and childhood obesity: A prospective, observational analysis. *Lancet*, 357, 505–508.
- Miller, JZ, Kimes, T, Hui, S., Andon, MB, & Johnston, CC Jr. (1991). Nutrient intake variability in a pediatric population: Implications for study design. *Journal of Nutrition*, 121, 265–274.
- Ministry of Health. (2003) New Zealand Food: New Zealand Children: Results of the 2002 National Children's Nutrition Survey.
- Ministry of Health. (2015) Annual Update of Key Results 2014/15: New Zealand Health Survey.
- Nelson, M., Black, A. E., Morris, J. A., & Cole, T. J. (1989). Between- and within-subject variation in nutrient intake from infancy to old age: Estimating the number of days required to rank dietary intakes with desired precision. *American Journal of Clinical Nutrition*, 50, 155–167.
- National Health and Medical Research Council (2006) Nutrient reference values for Australia and New Zealand including recommended dietary intakes. NHMRC: Canberra.
- Ondrak, K. S., & Morgan, D. W. (2007). Physical activity, calcium intake and bone health in children and adolescents. *Sports Medicine*, 37, 587–601.
- Saenger, P., Czernichow, P., Hughes, I., & Reiter, E. O. (2007). Small for gestational age: Short stature and beyond. *Endocrine Reviews*, 28, 219–251.
- Schofield, W. N. (1985). Predicting basal metabolic rate, new standards and review of previous work. *Human Nutrition—Clinical Nutrition*, 39, 5–41.
- Singer, M. R., Moore, L. L., Garrahe, E. J., & Ellison, R. C. (1995). The tracking of nutrient intake in young children: The Framingham Children's Study. *American Journal of Public Health*, 85, 1673–1677.
- Stettler, N., Kumanyika, S. K., Katz, S. H., Zemel, B. S., & Stallings, V. A. (2003). Rapid weight gain during infancy and obesity in young adulthood in a cohort of African Americans. *American Journal of Clinical Nutrition*, 77, 1374–1378.

- Swinburn, B. A., Caterson, I., Seidell, J. C., & James, W. P. (2004). Diet, nutrition and the prevention of excess weight gain and obesity. *Public Health Nutrition*, 7, 123–146.
- Theodore, R., Thompson, J., Wall, C., Becroft, D., Robinson, E., Clark, P., ... Mitchell, E. (2006). Dietary patterns of New Zealand European preschool children. *New Zealand Medical Journal*, 119, u1998.
- Thompson, J. M., Clark, P. M., Robinson, E., Becroft, D. M., Pattison, N. S., Glavish, N., ... Mitchell, E. A. (2001). Risk factors for small-for-gestational-age babies: The Auckland Birthweight Collaborative Study. *Journal of Paediatrics and Child Health*, 37, 369–375.
- Thomson, C. D., Mclachlan, S. K., Parnell, W. R., Wilson, N., Wohlers, M., Scragg, R., ... Fitzgerald, E. D. (2007). Serum selenium concentrations and dietary selenium intake of New Zealand children aged 5–14 years. *British Journal of Nutrition*, 97, 357–364.
- Tukey, J. (1977) *Exploratory data analysis*, 506 Addison-Wesley Reading, MA.
- Utter, J., Scragg, R., Mhurchu, C. N., & Schaaf, D. (2007). At-home breakfast consumption among New Zealand children: Associations with body mass index and related nutrition behaviors. *Journal of the American Dietetic Association*, 107, 570–576.
- Wells, J. C. K. (2011). The thrifty phenotype: An adaptation in growth or metabolism? *American Journal of Human Biology*, 23, 65–75.
- World Health Organisation. (2015). *Guideline: Sugars intake for adults and Children*.

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