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Dietary salt intake assessed by 24 h urinary sodium excretion in Australian schoolchildren aged 5–13 years

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Abstract

Objective: To measure total daily salt intake using 24 h urinary Na excretion within a sample of Victorian schoolchildren aged 5–13 years and to assess discretionary salt use habits of children and parents.
Design: Cross-sectional study.
Setting: Completed within a convenience sample of independent primary schools (*n* 9) located in Victoria, Australia.
Subjects: Two hundred and sixty children completed a 24 h urine collection over a school (34 %) or non-school day (66 %). Samples deemed incomplete (*n* 18), an over-collection (*n* 1) or that were incorrectly processed at the laboratory (*n* 3) were excluded.
Results: The sample comprised 120 boys and 118 girls with a mean age of 9·8 (SD 1·7) years. The average 24 h urinary Na excretion (*n* 238) was 103 (SD 43) mmol/24 h (salt equivalent 6·0 (SD 2·5) g/d). Daily Na excretion did not differ by sex; boys 105 (SD 46) mmol/24 h (salt equivalent 6·1 (SD 2·7) g/d) and girls 100 (SD 41) mmol/24 h (salt equivalent 5·9 (SD 2·4) g/d; $P = 0{\cdot}38$). Sixty-nine per cent of children (*n* 164) exceeded the recommended daily Upper Limit for Na. Reported discretionary salt use was common: two-thirds of parents reported adding salt during cooking and almost half of children reported adding salt at the table.
Conclusions: The majority of children had salt intakes exceeding the recommended daily Upper Limit. Strategies to lower salt intake in children are urgently required, and should include product reformulation of lower-sodium food products combined with interventions targeting discretionary salt use within the home.

Keywords
Sodium chloride
Dietary
Sodium
Dietary
Child
Australia

In developed countries, children aged 5 years and over frequently exceed the dietary recommendation for salt by more than 50 %, with intakes estimated at 6 g or more/d (2400 mg Na/d)[1]. A high Na intake during childhood increases the risk of the early development of cardiovascular risk factors such as raised blood pressure[2,3] and potentially obesity, as a high salt intake stimulates thirst[4] and have been associated with the consumption of high-energy sugar-sweetened beverages[5–7]. Furthermore, as a preference for salted foods is likely to develop early in life[8–10], exposure to highly salted foods during childhood may program children to a lifelong appetite for saltier foods.

Obtaining an accurate measure of dietary Na intake can be challenging. Dietary records tend to underestimate Na intake[7] as they exclude salt added during cooking and at the table, are prone to self-reporting errors and are limited by the quality and completeness of food composition databases[11–13]. The most recent national estimates of Na intake in Australian children are derived from 24 h dietary recall data completed within the 2007 National Children's Nutrition and Physical Activity Survey (CNPAS)[14]. The average Na intake of 4–8-year-olds and 9–13-year-olds was high, 2161 mg/d (salt equivalent 5·5 g/d) and 2694 mg/d (salt equivalent 6·9 g/d), respectively, and exceeded the daily Upper Limit by 1·3–1·5 times[14,15]. As this measure does not include salt added at the table and during cooking, it is likely to be an underestimate. The most objective indicator of salt intake is the measurement of 24 h urinary Na, as approximately 95 % of dietary salt consumed is excreted in the urine[16]. Within the context of population salt reduction initiatives, which are increasingly being implemented worldwide[17], the WHO emphasises the importance of monitoring population salt intake and recommends, where possible, this be undertaken using 24 h urine collections[18]. However, perhaps in part due to the high participant burden and logistical difficulties in collecting complete 24 h urine samples, in particular with children, an accurate measure of salt intake using 24 h urinary Na in Australian children had not previously been undertaken. To our knowledge only one small study (*n* 12) in the 1980s

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used 24 h urinary Na as a marker for salt intake in children of pre-school age[19]. In that study the average Na intake was 67 mmol/d (salt equivalent 3·9 g/d)[19]. One other Australian study in adolescents aged 11–14 years reported a 24 h urinary Na excretion of 160 mmol/d (salt equivalent 9·4 g/d); however, this was predicted by a morning spot urine rather than 24 h urine collection[20]. The aim of the present study was to objectively measure total daily salt intake using 24 h urinary Na excretion in a sample of Victorian schoolchildren aged 5–13 years. In addition we assessed discretionary salt use habits of children and parents.

Methods

Participants

Participants included primary-school children aged 5–13 years attending independently funded schools located within Victoria, Australia. A web-based school locater search engine was used to identify all those independent Victorian schools with enrolments of primary-school children (*n* 193)[21]. A convenience sample of schools was selected from the listing, and principals were contacted via an official letter of invitation and a telephone call, inviting school participation in the study. In total 104 schools were invited, of which nine agreed to participate in the study (response rate = 9 %). A short presentation, outlining the purpose of the study, was presented to students at the school assembly, after which students were provided with written materials, addressed to parents, inviting them to take part in the study. Of the potential 1464 students, 269 agreed to study participation (response rate = 18 %), nine of these children later dropped out of the study. Reasons for attrition included no longer interested in participating (*n* 3), being either absent on the day of data collection (*n* 5) or no longer attending the school (*n* 1). Written consent was obtained from the child, as well as the child's parent/caregiver. The study was approved by the Deakin University Human Research Ethics Committee.

Data collection and measures

Data were collected at participating schools across two time blocks, June–December 2010 and May–June 2011. A team of research assistants visited participating schools to support children to complete the 24 h urine collection and to collect anthropometry.

Demographic characteristics and discretionary salt use habits

The parent of each child completed a health information questionnaire. The questionnaire collected information on the child's age, gender, birth weight, existing medical conditions and use of medications or dietary supplements. In addition three questions assessed discretionary salt use habits, two of which applied to the parent's use of salt, 'Q1: Do you add salt during cooking?' (used previously in 2007 CNPAS[22]) and 'Q2: Do you place a salt shaker on your table at meal times?', and one question related to the child's own use of salt at meal times, 'Q3: Does your child add salt to their meal at the table or sandwich preparation?' For each of these questions parents could respond 'yes, usually', 'yes, sometimes', 'no' or 'don't know'. At school on the day of data collection, the study child was also questioned about his/her own use of table salt. Children were asked 'Do you add salt to your meal at the table?' (used previously in 2007 CNPAS[22]), to which they could respond 'yes, usually', 'yes, sometimes' or 'no'.

24 h Urine collection and laboratory analysis

Collection protocol. Participants could commence the 24 h urine collection either at school or at home over the weekend. Written instructions, tailored for either a school or weekend day collection, were provided for parents, and simplified pictorial instructions were provided for children. All children were instructed to commence the collection by emptying their bladder, discarding this urine and noting this as the 24 h collection start time. During the 24 h following this all urine voided was collected. Children finished the collection with a final void at the corresponding 24 h finish time. Urine was collected in 2·5-litre wide-rimmed mouthed polypropylene bottles. To assist with urine collection an additional 500 ml plastic handled jug was provided.

School day collections commenced at the start of school (i.e. 08.30–09.30 hours) and at the end of the school day (i.e. 15.00–15.30 hours) children collected their materials to continue the collection at home. On the following school day, at the commencement of school, children returned to research staff and finished the collection by providing a final void. Children completing the collection on a weekend day were able to commence the urine collection at any suitable 24 h period over the weekend, parents recorded start and finish times on a urine collection slip and children were instructed to return completed samples to research staff at school on the following Monday morning.

Urinalyses. Urinary Na concentration was assessed using indirect ion-selective electrodes and urinary creatinine concentration was assessed using the Jaffè reaction on the Siemens Advia 2400 analyser (Dorevitch Pathology, Melbourne, Australia; an NATA (National Association of Testing Authorities) and RCPA (Royal College of Pathologists of Australia) accredited pathology laboratory). Of the 260 children who commenced the 24 h urine collection three samples were not returned. Collections were considered incomplete and excluded (*n* 15) if urinary creatinine excretion was less than 0·1 mmol/kg body weight per d[23], and samples were considered to be an over-collection and excluded if urinary creatinine

(mmol/kg body weight per d)[23] and total volume exceeded the age- and gender-specific 95th percentile (*n* 1).

Anthropometric measures

Height and body weight were measured in participants wearing light clothing, with shoes removed[24]. A calibrated portable stadiometer SECA model 220 (Hamburg, Germany) was used to measure height to the nearest 0·1 cm and calibrated Scaleman FS-127-BRW portable electronic scales (Bradman, MA, USA) were used to measure weight to the nearest 0·1 kg. BMI was calculated as body weight (kg) divided by the square of body height (m^2). Participants were grouped into weight categories (very underweight, underweight, healthy weight, overweight, obese) using the International Obesity Taskforce BMI reference cut-offs for children[25,26].

Statistical analysis

All statistical analyses were completed using the statistical software package STATA/SE 11. A P value of $<0{\cdot}05$ was considered significant. Descriptive results are presented as the mean and standard deviation or number and percentage where appropriate. All continuous variables were normally distributed. To compare the difference in mean values of continuous variables an independent t test was used; to compare differences in proportions between categorical variables, a χ^2 test was used. Pearson's correlation coefficient was used to assess the association between 24 h urinary Na excretion and BMI. The results for 24 h urinary Na excretion data are presented as mmol/24 h as well as the salt equivalent. To calculate the salt equivalent (g/d), daily Na was converted from mmol to mg, using the molar mass of Na of 23 mg/mmol, and then multiplied by 2·56. To assess the association between urinary Na excretion and type of day the collection was completed on (i.e. weekend or holiday *v.* school day), linear regression was used to allow for the adjustment for age, gender and BMI. Results are stratified by gender, as well as age group (5–8 years and 9–13 years), according to National Health and Medical Research Council age-specific dietary recommendations[15].

Results

Basic characteristics of the 238 children with complete 24 h urine collections are described in Table 1. Sixteen children (6 %) were deemed to have inaccurate urine collections, fifteen were under-collected and one was over-collected. These children did not differ from those children with complete urine collections by age or gender. Three samples were not returned and three were not available due to laboratory error in processing samples. The average age of participants was 9·8 (SD 1·7) years; gender was evenly distributed within the whole sample, as well as each of the age cohorts (i.e. 5–8 years, 9–13 years). Two-thirds (66 %) of children completed the 24 h urine collection on a weekend day.

The mean 24 h urinary Na excretion was 103 (SD 43) mmol/24 h, range 13–310 mmol/24 h (salt equivalent 6·0 (SD 2·5) g/d, range 0·8–18·1 g/d). There was a small significant positive correlation between 24 h urinary Na excretion and BMI ($r = 0{\cdot}23$, $P = 0{\cdot}003$). Daily urinary Na excretion did not differ by gender (Table 1). When stratified by age group, daily urinary Na excretion was significantly greater in older children, 107 (SD 45) mmol/24 h (salt equivalent 6·3 (SD 2·6) g/d) in 9–13-year-olds *v.* 94 (SD 39) mmol/24 h (salt equivalent 5·5 (SD 2·3) g/d)

Table 1 Demographic characteristics, anthropometry and 24 h urinary sodium excretion of study participants by sex: primary-school children (*n* 238) attending nine independently funded schools, Victoria, Australia, June 2010–June 2011

	Total (*n* 238)		Boys (*n* 120)		Girls (*n* 118)		
Measure	Mean or *n*	SD or %	Mean or *n*	SD or %	Mean or *n*	SD or %	*P* value*
Age (years)	9·8	1·7	9·8	1·7	9·9	1·7	0·97
Age group (%)†							
5–8 years	83	35	42	51	41	49	0·97
9–13 years	155	65	78	50	77	50	
Weight (kg)	35·4	8·9	35·2	9·1	35·6	8·6	0·72
Height (cm)	140·6	11·3	140·7	11·8	140·5	11·0	0·87
BMI (kg/m^2)	17·7	2·4	17·6	2·3	17·8	2·4	0·47
Weight classification (%)†,‡							
Healthy weight	197	82·8	103	85·8	94	79·7	0·63
Overweight	30	12·6	12	10·0	18	15·3	
Obese	4	1·7	2	1·7	2	1·7	
Underweight	7	2·9	3	2·5	4	3·4	
Day type of urine collection (%)†							
School day	80	34	46	58	34	42	0·12
Weekend day/public holiday	158	66	74	47	84	53	
Urinary Na excretion (mmol/24 h)	103	43	105	46	100	41	0·38
Salt equivalent (g/d)	6·0	2·5	6·1	2·7	5·9	2.4	

*P values determined using the independent t test or χ^2 test.
†Data are presented as *n* (%).
‡Weight classification based on the International Obesity Taskforce BMI reference cut-offs[25,26].

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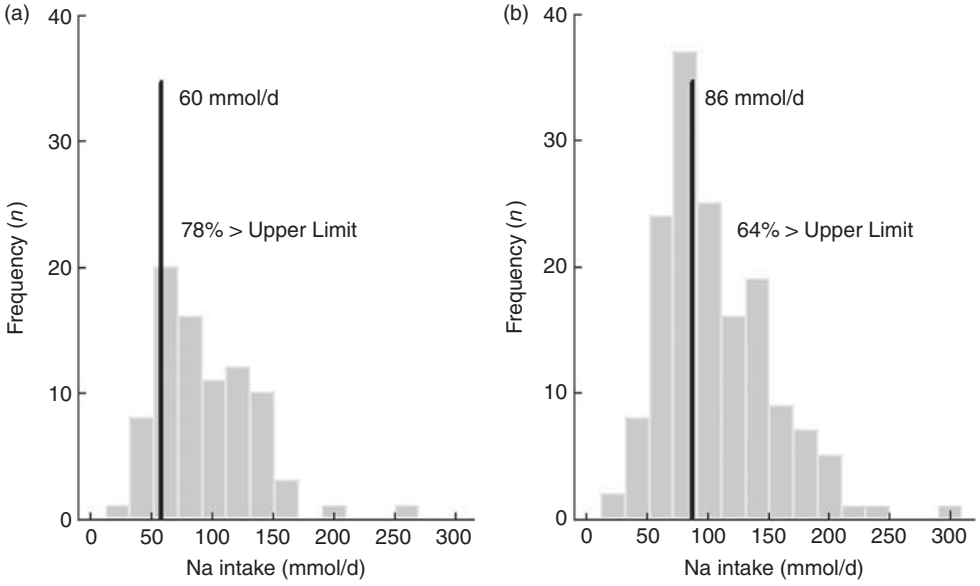

Fig. 1 Daily sodium intake (mmol/d) compared with dietary recommendations (Upper Limit: 4–8 years = 60 mmol/d; 9–13 years = 86 mmol/d[15]) by age group: (a) 5–8 years (*n* 83); (b) 9–13 years (*n* 155). Primary-school children attending nine independently funded schools, Victoria, Australia, June 2010–June 2011

in 5–8-year-olds ($P = 0{\cdot}03$). Sixty-nine per cent (*n* 164) of children exceeded the age-specific recommended daily Upper Limit for Na intake (4–8 years = 60 mmol/d; 9–13 years = 86 mmol/d). Children aged 5–8 years children were more likely to exceed the daily Upper Limit ($\chi^2 = 5{\cdot}3$, $P = 0{\cdot}02$; Fig. 1). In both age cohorts the range of Na intake was large, with maximum values of 262 mmol/24 h (salt equivalent 15·3 g/d) and 310 mmol/24 h (salt equivalent 18·1 g/d) in 5–8-year-olds and 9–13-year-olds, respectively (Fig. 1).

Including all children, daily urinary Na excretion was significantly greater on non-school days, 110 (SD 45) mmol/24 h (salt equivalent 6·4 (SD 2·6) g/d), compared with schools days, 89 (SD 37) mmol/24 h (salt equivalent 5·2 (SD 2·1) g/d; $P = 0{\cdot}001$). After adjustment for age, gender and BMI, urinary Na excretion was 22 (SD 6) mmol/24 h (salt equivalent 1·3 (SD 0·2) g/d) greater on a non-school day compared with a school day collection ($P < 0{\cdot}001$).

Discretionary salt use habits of participants and their parents/caregivers are described in Fig. 2. Two-thirds of parents/caregivers reported adding salt during cooking either usually or sometimes and approximately one-third reported placing a salt shaker on the table at meal times either usually or sometimes. Thirty-seven per cent of parents reported that their child adds salt at the table either usually or sometimes. However, when children were asked to self-report on their own salt use at the table the proportion was greater, with 47 % reporting adding salt at the table usually or sometimes. There was no association between the child's gender or age group and any of the four discretionary salt use habits (data not shown). Furthermore, for each of the four discretionary salt use habits there was no difference in mean 24 h urinary Na excretion between those children who added salt usually or sometimes and those children who did not add salt (data not shown).

Discussion

To our knowledge, the present study is the first Australian one to use 24 h urinary Na excretion as a marker to assess salt intake in children aged 5–13 years. Within this sample, over two-thirds of children exceed the recommended daily Upper Limit with an average salt intake of 6·0 g/d (103 mmol Na/d). These data are comparable to findings from similar small studies completed in young European[27–29] and US[30] children where Na excretion was approximately 100 mmol/d. In contrast to previous studies[1], which have reported higher salt intake in boys, we did not find any gender differences in salt intake. This may be due to our relatively modest sample size.

The salt intakes calculated from the 24 h urine collections (5·5 g/d in 5–8-year-olds; 6·3 g/d in 9–13-year-olds) are similar to the most recent national estimates of salt intake in Australian children (5·4 g/d in 4–8-year-olds; 6·7 g/d in 9–13-year-olds) which were based on 24 h dietary recall[14]. Compared with national estimates, it would be expected that salt intake as measured by 24 h urine collection, which includes salt added at the table and during cooking, would be greater. However, this is not the case in 9–13-year-olds and is likely a result of the differences in sampling framework (convenience sample *v.* nationally representative survey) and sample size (*n* 238 *v.* *n* 1000). Furthermore, as study participants were recruited from privately funded schools they are

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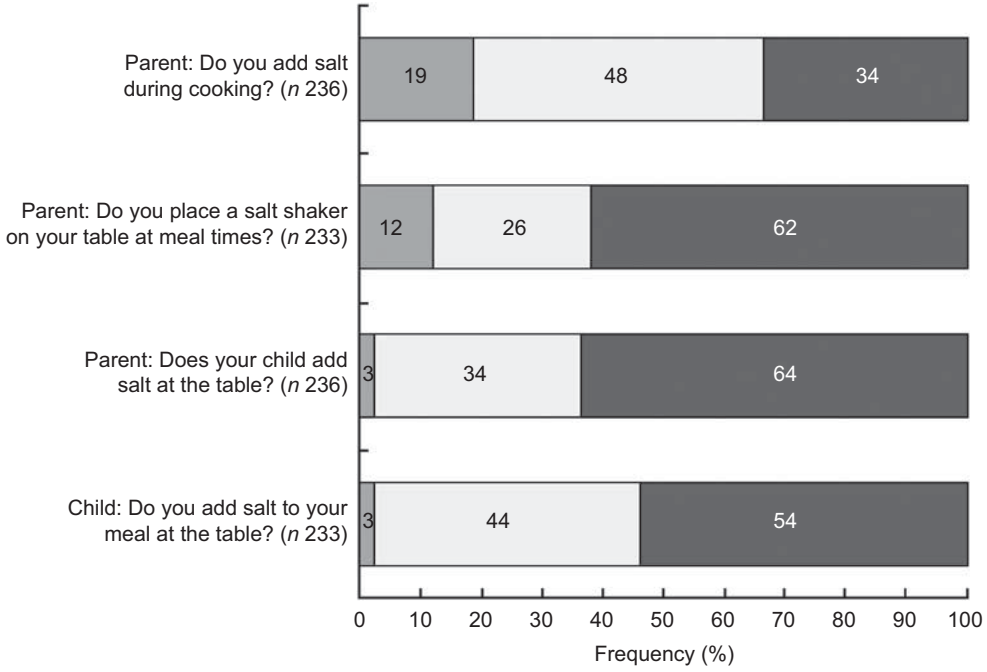

Fig. 2 Discretionary salt use habits of study participants and their parents (■, 'yes, usually'; □, 'yes, sometimes'; ■, 'no'). Primary-school children (*n* 238) attending nine independently funded schools, Victoria, Australia, June 2010–June 2011

likely to represent the most socio-economically advantaged population groups and not be representative of the general population. This is indicated by the lower prevalence of overweight and obesity in our sample (14 %) compared with national estimates, which indicate 25 % of 2–16-year-olds are overweight or obese[14]. National data in Australian children indicate that salt intake is greater in those of lower socio-economic backgrounds[31]. Consistent with national estimates on discretionary salt use, where approximately 30 % and 40 % of 4–13-year-olds reported adding salt at the table and parents reported adding salt during cooking, respectively[32], we found the addition of salt to food during cooking and at the table was relatively common. It might be expected that daily salt intake would be greater in children who are exposed to discretionary salt. For example in Australian adults daily urinary Na excretion was found to be 19 % greater in those who reported adding salt during cooking[33]. However, in the present study we found no difference in daily urinary Na excretion between users or non-users of discretionary salt. This may be due to our relatively modest sample size or the use of one 24 h urine collection for Na assessment compared with general use of discretionary salt. It is a concerning finding that approximately half of children reported adding salt at the table. As dietary habits formed in childhood may influence dietary patterns later in life[34], it is important that children adopt good food habits from an early age. Furthermore, salt added to table food is likely to be more available to taste than salt within the food matrix (i.e. added during manufacture)[35,36], and evidence from adults[37] and children[38] suggest that a high salt sensory experience may increase the taste preference for highly salted foods. As such, it is important that Na reduction interventions include strategies to reduce discretionary salt use in children.

We found salt intake was significantly greater on non-school days, compared with school days. This finding is not surprising, given that energy consumption is greater on weekends[39] and food choices on the whole tend to be poorer, with the inclusion of more 'unhealthy' foods[40]. Although lower intakes of salt were recorded on school days, the average intake still exceeded the recommended daily Upper Limit. Many everyday food items, which are likely to be included in packed school lunches, contribute significant levels of salt to the diets of Australian children; these include bread, processed meats (i.e. ham), cheese, biscuits, savoury snacks and yeast spreads (i.e. vegemite)[32].

In developed countries, most (75 %) dietary Na is derived from salt added to processed foods[41]. Therefore, to achieve substantial reductions in population salt intake there is a need to reduce the amount of salt added to food during manufacture[42]. The findings from our study provide evidence of high salt consumption in Victorian schoolchildren and emphasise the urgent need for salt reduction strategies in children. To achieve substantial reductions in children's salt consumption, ongoing and considerable reductions in the amount of salt added to food during manufacturing are required[42]. This should be combined with interventions that target discretionary salt use in the home.

In the development of a salt reduction policy in Australia, appropriate measures to monitor and track progress over

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time, which include a reliable measure of salt intake, need to be considered[18]. With just 6 % of urine samples being incomplete or in error (this compares with 1 % of under-collections in adult surveys[43]), our findings demonstrate that the collection of 24 h urinary Na data in young children attending Australian schools is feasible and that this approach could be incorporated into a national monitoring system. In the USA, the collection of 24 h urine samples within a nationally representative sample of the population, including children, has been recommended to monitor salt intake and track progress relative to salt reduction work occurring within the US food supply[44]. Similarly in the most recent 2008/09–2009/10 UK National Diet and Nutrition Survey, 24 h urine collections were used to assess salt intake in children aged 4–18 years (data not yet released)[45].

The important strength of the present study is the use of an objective indicator, 24 h urinary Na, to measure total salt intake. In addition, we used a well-devised 24 h urine collection protocol, tailored specifically to children. We acknowledge that 24 h urine samples were only collected during 8 months of the year and that salt consumption may vary across seasons. However, as this time period captures the Australian winter, spring and some of summer and autumn, it is likely that any seasonal effect on salt intake would be minimal. The limitations of the present study are the relatively small sample size (n 238) and the low rate of recruitment (18 %) from a sample of children with high socio-economic status. These limitations have implications for the generalisability of our findings. However, it is important to note that given the inverse associations between socio-economic status and salt consumption in children[31], these findings likely represent a best-case scenario and may indicate that salt intakes (as reflected by 24 h urinary Na) in samples with lower socio-economic status are likely to be higher than those shown here.

Conclusions

The present study suggests that the collection of 24 h urine samples to objectively assess salt intake in young children is feasible within the Australian school setting. The salt intake in this small sample of children was high. Further research is needed to more clearly elucidate salt consumption in a larger and more representative sample of children. Understanding children's salt consumption is vitally important given the known associations between salt consumption and life-course progression to hypertension.

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