Salt Intake of Children and Adolescents in South London
Consumption Levels and Dietary Sources

Naomi M. Marrero, Feng J. He, Peter Whincup, Graham A. MacGregor

See Editorial Commentary, pp 911–912

Abstract—Since 2003/2004, the United Kingdom has implemented a salt reduction campaign; however, there are no data on salt intake in children as assessed by 24-hour urinary sodium, the gold standard method, to inform this campaign. We performed a cross-sectional study, involving South London school children across 3 age tiers: young children (5- to 6-year olds), intermediate-aged children (8- to 9-year olds), and adolescents (13- to 17-year olds). Dietary salt intake was measured by 24-hour urinary sodium excretion and compared with newly derived maximum salt intake recommendations. In addition, dietary sources of salt were assessed using a 24-hour photographic food diary. Valid urine collections were provided by 340 children (162 girls, 178 boys). The mean salt intakes were 3.75 g/d (95% confidence interval, 3.49–4.01), 4.72 g/d (4.33–5.11), and 7.55 g/d (6.88–8.22) for the 5- to 6-year olds, 8- to 9-year olds, and 13- to 17-year olds, respectively. Sixty-six percent of the 5- to 6-year olds, 73% of the 8- to 9-year olds, and 73% of 13- to 17-year olds had salt intake above their maximum daily intake recommendations. The major sources of dietary salt intake were cereal and cereal-based products (36%, which included bread 15%), meat products (19%), and milk and milk products (11%). This study demonstrates that salt intake in children in South London is high, with most of the salt coming from processed foods. Much further effort is required to reduce the salt content of manufactured foods. (Hypertension. 2014;63:1026-1032.)

Key Words: adolescent ■ child ■ sodium chloride, dietary

Raised blood pressure (BP) throughout its range is a major cause of cardiovascular disease.1 Although raised BP and cardiovascular disease typically present in adults, the origins commonly begin in childhood. BP has been shown to follow a tracking pattern, and those children who have BP at the higher end of the BP distribution are more likely to develop high BP as adults.2–5 Therefore, it is important to start interventions to lower BP levels in children and to prevent the rise in BP with age, particularly because there has been a trend of increase in British children’s systolic BP during the past 3 decades.6 Studies investigating the role of salt intake in BP in children demonstrate that a reduction in salt intake significantly lowers BP.7 In 2003/2004, the UK Food Standards Agency along with Consensus Action on Salt & Health, an Nongovernmental Organization, implemented a national salt reduction program. The World Health Organization recommends that to guide and inform such salt reduction initiatives, salt intake within a population should be monitored and that where possible this should be measured by 24-hour urinary sodium (the gold standard method).8 Although 24-hour urinary sodium has been measured in the adult population in the United Kingdom every 3 to 5 years,9 there is only 1 small study (n=34) in the United Kingdom that has measured 24-hour urinary sodium in school children.10 The study was done in the mid-1980s in a group of 4- to 6-year olds. The average salt intake at that time was 3.8 g/d. Since this study, dietary practices have changed considerably, with processed and fast foods contributing a larger part than ever to children’s diets.11

The aim of this study was, therefore, to determine current salt intake in children and adolescents by measuring 24-hour urinary sodium excretion, to compare these intakes against newly derived maximum salt intake recommendations, and to identify the major sources of salt in children’s diets by a photographic dietary record.

Subjects and Methods

We performed a cross-sectional study to determine the salt intake of children within 3 age tiers (ie, young [5- to 6-year olds], intermediate [8- to 9-year olds], and adolescents [13- to 17-year olds]). The study was performed between October 2007 and June 2010. The methods are given in brief below. A detailed description is provided in the online-only Data Supplement.

Figure 1 illustrates the recruitment of participants into the study. Participants were mainly recruited from schools within the London
Boroughs of Wandsworth, Sutton, and Merton. Head teachers from randomly selected primary and secondary schools were contacted via an invitation letter and a phone call to request their school’s participation in the study. In addition, St. George’s University of London ran a Spring School to educate teenagers (14–15 years old) from London schools about careers in health care. Attendees of the Spring School were also invited to participate in the study.

The study was approved by the Royal Marsden Research Ethics Committee. Written consent was obtained from the parent/caregiver, as well as children aged ≥8 years.

**24-Hour Urine Collection**

All children who entered the study were asked to complete a 24-hour urine collection. Participants and the parents of the 5- to 6-year olds were given both verbal and illustrated written instructions on how to complete the urine collection. They were told not to change any dietary habits during the data collection period.

The urine samples were measured for 24-hour urine volume, sodium, potassium, and creatinine. Urinary sodium and potassium were measured using indirect ion-selective electrodes. Initially, urinary creatinine was measured using the Jaffe method; however, midway through the study, the machines were replaced and in the later stages the enzymatic assay method was used.

Collections were deemed incomplete if the participant admitted to have missed ≥1 urine collection or if they had a 24-hour urinary creatinine of <0.1 mmol/kg per day12 or they had a reduced urine output of <0.5 mL/kg per hour for the 5- to 6- and 8- to 9-year olds or <500 mL/24 hours for the 13- to 17-year olds.13 Urine samples were also deemed incomplete if the timing of the collection was <20 hours or >28 hours.

**Maximum Salt Intake Recommendations**

Children’s salt intake was compared against maximum salt intake recommendations. Although guidelines do exist in the United Kingdom for children and adults, unlike the recommendation for adults, the children’s recommendations are not based on reliable data.14 Therefore, new maximum recommendations were calculated for each age group. These recommendations are based on the Scientific Advisory Committee on Nutrition (SACN) recommendation for adults of 6 g/d,14 which has been adjusted downwards based on the average body surface area of children relative to those of adults (Table 1). From these calculations, we propose the following maximum daily salt intake recommendations for children: 2 g for 3- to 4-year-old children, 3 g for 5- to 8-year-old children, 4 g for 9- to 11-year-old children, 5 g for 12- to 15-year-old children, and 6 g for children aged ≥16 years.

**Table 1. Salt Intake Recommendations Based on BSA**

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Height, cm</th>
<th>Weight, kg</th>
<th>BSA, m²</th>
<th>Salt, g/d</th>
<th>Recommended Maximum Daily Intake, g/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>98.64</td>
<td>16.07</td>
<td>0.66</td>
<td>2.10</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>105.52</td>
<td>18.30</td>
<td>0.73</td>
<td>2.31</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>112.84</td>
<td>20.68</td>
<td>0.81</td>
<td>2.54</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>120.27</td>
<td>24.60</td>
<td>0.91</td>
<td>2.87</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>126.56</td>
<td>27.16</td>
<td>0.98</td>
<td>3.09</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>132.49</td>
<td>30.77</td>
<td>1.06</td>
<td>3.36</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>136.78</td>
<td>32.79</td>
<td>1.12</td>
<td>3.53</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>142.28</td>
<td>38.18</td>
<td>1.23</td>
<td>3.88</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>149.86</td>
<td>45.69</td>
<td>1.38</td>
<td>4.36</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>154.59</td>
<td>48.70</td>
<td>1.45</td>
<td>4.57</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>161.17</td>
<td>54.87</td>
<td>1.57</td>
<td>4.95</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>164.73</td>
<td>60.80</td>
<td>1.67</td>
<td>5.27</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>166.90</td>
<td>63.16</td>
<td>1.71</td>
<td>5.41</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>170.93</td>
<td>64.92</td>
<td>1.76</td>
<td>5.55</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>169.42</td>
<td>65.77</td>
<td>1.76</td>
<td>5.56</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>172.19</td>
<td>68.84</td>
<td>1.81</td>
<td>5.74</td>
<td>6</td>
</tr>
<tr>
<td>Adults (≥19)</td>
<td>167.72</td>
<td>77.35</td>
<td>1.90</td>
<td>6.00</td>
<td>6</td>
</tr>
</tbody>
</table>

Maximum salt intake recommendation calculated from the Scientific Advisory Committee on Nutrition recommendation for adults of 6 g/d,14 which has been adjusted downwards based on the average BSA of children relative to those of adults. BSA calculated from height and weight data obtained from the National Diet and Nutrition Survey rolling survey.15 The formula used was $\sqrt{\text{wt (kg)} \times \text{ht (cm)}}/3600$. BSA indicates body surface area.
There was an increase in salt intake with age. The mean salt intake as calculated by 24-hour urinary sodium excretion was 3.75 g/d (95% confidence interval 3.45–4.06). Table 2 provides mean sodium excretion by age group and sex. Figure 1 provides box plots of sodium excretion by age group and sex. There was a greater contribution to salt intake from the 5- to 6-year-olds (3.75 g/d) than from the 8- to 9-year-olds (2.90 g/d) and from the 13- to 17-year-olds (2.90 g/d). The total number of children who were invited to participate in the study was 1807. Of these, 433 urine samples were returned, 93 (21%) were incomplete, and 38 had a collection timing of >28 hours. The response rate was highest for the 8- to 9-year-old (52%) and lowest for the 13- to 17-year-old age group (17%). The response rate was lower when the children were requested to complete the collection at school term time (12% versus 45% and 4% versus 30% for the 5- to 6-year-olds and 8- to 9-year-olds, respectively).

Table 2. Salt Intakes as Measured by 24-Hour Urinary Sodium Excretion by Age Group and Sex

<table>
<thead>
<tr>
<th>Urinary Measurements</th>
<th>All (n=126)</th>
<th>5- to 6-Year-Olds</th>
<th>8- to 9-Year-Olds</th>
<th>13- to 17-Year-Olds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium excretion, mmol/24 h</td>
<td>Mean±SE 95% CI</td>
<td>Mean±SE 95% CI</td>
<td>Mean±SE 95% CI</td>
<td>Mean±SE 95% CI</td>
</tr>
<tr>
<td>Creatinine excretion, mmol/24 h</td>
<td>Mean±SE 95% CI</td>
<td>Mean±SE 95% CI</td>
<td>Mean±SE 95% CI</td>
<td>Mean±SE 95% CI</td>
</tr>
<tr>
<td>Number above maximum salt intake recommendation*</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

*The body surface area–based maximum recommendation is 3 g salt/d for 5- to 8-year-olds, 4 g/d for 9- to 11-year-olds, 5 g/d for 12- to 15-year-olds, and 6 g/d for ≥16 y. CI indicates confidence interval.
interval, 3.49–4.01), which increased to 7.55 g/d (6.88–8.22) for the 13- to 17-year-olds. This increase in salt intake with age was significant for the group as a whole ($P<0.001$) and also for boys ($P<0.001$) and girls separately ($P<0.001$). Salt intake was significantly higher in boys compared with girls in the 5- to 6-year age group ($P=0.004$) and in the 13- to 17-year age group ($P<0.001$), but there was no significant difference in salt intake between boys and girls in the 8- to 9-year age group ($P=0.775$; Table 2).

Seventy percent of participants (66% of 5- to 6-year-olds, 73% of 8- to 9-year-olds, and 73% of 13- to 17-year-olds) had salt intake above their respective maximum intake recommendation (3 g/d for 5- to 8-year-olds, 4 g/d for 9- to 11-year-olds, 5 g/d for 12- to 15-year-olds, and 6 g/d for ≥16 years). The proportion with a salt intake above the recommendation was consistently higher in boys than in girls for each age group (Table 2).

**Dietary Sources of Salt**

The major food sources of salt in the participants’ diets are shown in Figure 2. Cereals and cereal products contributed the most salt to children’s diets across all age groups, accounting for 36% of total salt intake as calculated from the photographic food diary for all participants. This was followed by meat products (19%) and milk and milk products (11%). The contribution of milk and milk products to dietary salt intake declined with age, contributing 15% of salt intake in the 5- to 6-year-olds and 9% in the teenagers. However, the contribution of vegetable and potato products (ie, vegetable-based dishes including curries and stew, canned vegetables) to salt intake increased with age. This category contributed to 7% of salt intake in the 5- to 6-year-olds compared with 10% in the teenagers. The contribution of meat products to salt intake showed a similar trend of increase with age, contributing 17% of salt intake in the 5- to 6-year-olds and 20% in the teenagers. The contribution of salt intake from the other major food categories was fairly consistent across all age groups.

Table 3 shows a further breakdown of the different food categories to salt intake. Within cereal and cereal products, bread contributed to 15% of total salt intake, breakfast cereals to 10%, biscuits, cakes, and others to 5%, and pasta, rice, and other cereal-based products to 6% of salt intake. Within the meat products category, chicken and turkey dishes contributed to 5% of total salt intake, sausages to 5%, and bacon and ham to 4%. Within milk and milk products, cheese contributed to 5% of total salt intake and milk to 4%. Other significant contributors to salt intake in all participants included savory snacks, sauces, and soups that contributed to 5%, 6%, and 2% of salt intake, respectively.

**Discussion**

**Dietary Salt Intake**

To our knowledge, this is the first study in the United Kingdom that has estimated salt intake in a large group of school children using 24-hour urinary sodium excretion, considered the gold standard method. Our results show that salt intake in children is high, 70% of participants had salt intake above their respective maximum intake recommendation. If anything, our study provides an underestimation of salt intake because of the limitations of the study, namely, the poor response rate, particularly in the 5- to 6-year-olds and 13- to 17-year-olds. Furthermore, despite the most careful collection and exclusion methods, it is possible that there are some individuals who undercollected 24-hour urine but escaped the exclusion criteria applied and were included in the analysis. Therefore, the results of our study likely present a best-case scenario of salt intake.

Although in the United Kingdom SACN has recommended maximum salt intakes for children, their recommendations are not based on any scientific rationale. Initially, the recommended levels were lower, and after consultations they were raised for unspecified reasons. For example, SACN advises 5 g/d for 7-year-olds, which is too high because the World Health...
Organization recommends that adults consume no more than 5 g/d.\textsuperscript{16} The SACN guideline for adults is based on 24-hour urinary sodium data in a nationally representative sample of adults, which reported an average daily salt intake of 9 g/d.\textsuperscript{17} SACN, therefore, recommended a reduction in the average intake of salt by the adult population to 6 g/d. However, there are no 24-hour urine data available in a nationally representative sample of children to inform similar recommendations for the younger population. In view of this, we have calculated salt intake recommendations for children based on the current recommendation in the United Kingdom for adults of 6 g/d and taking account of body surface area.\textsuperscript{14} When comparing the salt intake of the children to the newly derived maximum salt intake recommendations, it is clearly evident that average salt intake in children is high. Altogether, 70% had salt intake above their maximum daily intake recommendation. It is also important to note that these maximum salt intake recommendations are not what is considered optimal for health but what is achievable. Human physiological needs are considered to be much lower than the current UK SACN recommendation (eg, the Yanomamo Indians were shown to have a diet containing <0.5 g salt/d).\textsuperscript{18}

Our findings of a high salt intake in children are similar to data from recent studies in other Westernized societies, which also show salt intake in children is high across all age groups. For example, 24-hour urinary sodium excretion in a group of 6-year-old Finnish children showed a salt equivalent of 4.1 g/d.\textsuperscript{19} In 10- to 12-year-old Portuguese children, 24-hour urinary sodium excretion showed an average salt intake of 7.8 g/d.\textsuperscript{20} Similarly, a study in Australian private school children aged 5 to 13 years, which also collected 24-hour urine samples, showed an average salt intake of 6.0 g/d.\textsuperscript{21} A review by Brown \textit{et al}\textsuperscript{22} of 41 reports from 20 countries that had included salt intake as an outcome measure showed that in all age groups, in both sexes, in different countries throughout the world salt intake in children is high. For instance, in many countries, such as United States, Japan, and Australia, salt intake in adolescents was >12 g/d, but the majority of the studies did not measure 24-hour urinary sodium.\textsuperscript{22}

Our study also showed that salt intake increased with age and was also higher in boys than in girls for the 5- to 6- and 13- to 17-year age groups. These trends are consistent with the findings from other studies.\textsuperscript{22} A simple explanation for this

\begin{table}[h]
\centering
\caption{Percentage Contribution of Food Groups/Categories to Salt Intake}
\begin{tabular}{l|cccc}
\hline
\textbf{Food Group} & \textbf{All Participants} & \textbf{5- to 6-Year-Olds} & \textbf{8- to 9-Year-Olds} & \textbf{13- to 17-Year-Olds} \\
(n=431) & (n=145) & (n=164) & (n=122) \\
\hline
Cereal and cereal products & 36 & 37 & 37 & 36 \\
Breads & 15 & 16 & 17 & 13 \\
Breakfast cereals & 6 & 6 & 6 & 5 \\
Biscuits, cakes, puddings, scones, doughnuts & 5 & 5 & 5 & 5 \\
Sandwiches, burgers, filled wraps & 2 & 2 & 1 & 4 \\
Pizza & 3 & 3 & 3 & 3 \\
Pasta, rice, and other cereal-based products & 6 & 5 & 5 & 7 \\
Meat products & 19 & 17 & 19 & 20 \\
Chicken and turkey dishes & 5 & 3 & 4 & 7 \\
Sausages & 5 & 5 & 5 & 3 \\
Bacon and ham & 4 & 3 & 4 & 4 \\
Beef dishes & 3 & 3 & 3 & 2 \\
Milk and milk products & 11 & 15 & 10 & 9 \\
Milk and milk-based drinks & 4 & 5 & 4 & 3 \\
Cheese & 5 & 7 & 4 & 4 \\
Vegetable and potato products & 9 & 7 & 9 & 10 \\
Soups and sauces & 9 & 10 & 8 & 10 \\
Soups & 2 & 3 & 2 & 2 \\
Sauces & 6 & 6 & 6 & 7 \\
Savory snacks & 5 & 4 & 4 & 6 \\
Potato crisps & 2 & 1 & 3 & 4 \\
Fish and fish dishes & 3 & 2 & 5 & 2 \\
Oils and fats & 2 & 3 & 3 & 1 \\
Egg and egg dishes & 1 & 1 & 1 & 1 \\
Sugars, preserves, and confectionery & 1 & 1 & 1 & 1 \\
Other foods & 1 & 1 & 1 & 2 \\
\hline
\end{tabular}
\end{table}
is that older children have greater energy requirements than younger children, as do boys compared with girls, which leads to a greater total food consumption and, therefore, higher salt intake. The increase in salt intake and BP with age was considered inevitable; however, studies in the Yanomamo Indians and other isolated tribes have shown that this increase in salt intake with age does not have to be the common pattern. These groups of indigenous people have little salt in their diet, which does not increase with age and nor does their BP.18

The salt intake of the 5- to 6-year-olds in the current study is slightly lower than that of a similar age group of children studied in the 1980s, where the average urinary sodium was 64 mmol/24 hours (3.8 g salt/d).10 Since the 1980s, dietary habits have changed drastically with more processed and restaurant/fast foods being consumed, and it would be expected that salt intake now is higher than in the 1980s. The lower salt intake found in our study could, in part, be attributable to the poor response rate causing selection bias. It has been shown in many studies that respondents and nonrespondents differ from each other with regard to ethnic group, socioeconomic status, and healthy behavior; nonrespondents are more likely to have unhealthy diet and lifestyles.21 It is possible that the participants or their parents in our study are more health conscious and, therefore, have a lower salt intake than those who did not take part in the study. In particular, the response rate was low for the 13- to 17-year-old age group. At this age, individuals are more likely to be concerned about what their peers think, and the thought of completing the urine collection may have been viewed as uncool by the teenagers. In addition, the response rates for the 5- to 6- and 13- to 17-year-old children were lower when the children were requested to take part in the study during the school holidays versus during school term time (12% versus 45% and 4% versus 30% for the 5- to 6- and 13- to 17-year olds, respectively). The likely explanation for this is that the schools had a lot more involvement when the study was run during term time, which in turn meant there was more encouragement and reminders from the schools for children to participate in the research.

Sources of Salt in Children’s Diets
Since 2003/2004, the United Kingdom has carried out an extensive salt reduction campaign. The UK Food Standards Agency has set voluntary salt reduction targets for 80 categories of processed foods.24 Many manufacturers, retailers, and caterers have been reformulating products to achieve these targets and beyond. There has been significant progress to date. Running parallel to the food industry activity, a huge consumer awareness campaign has been launched via various media outlets largely through the work of Consensus Action on Salt & Health and the Food Standards Agency. As a result, the adult daily salt intake as measured by 24-hour urinary sodium excretion in the United Kingdom has fallen from an average of 9.5 g/d in 2001 to 8.1 g/d by June 2011 (ie, an ≈15% reduction). However, despite the progress made in salt reduction in the United Kingdom, our study shows that salt intake in children is still high. Because the majority of salt in children’s diets comes from manufactured food products, further reductions in the salt content of food products are required. Our study showed that the major contributors to salt in children’s diets are cereal and cereal products (36%), meat products (18%), and milk and milk products (11%). These findings are consistent with the latest National Diet and Nutrition Survey, which showed that the same food categories are responsible for the majority of salt intake in children and adults.25 Bread alone accounted for 15% of salt intake in our study population. Although many manufacturers have made significant reductions in the sodium content of their bread, a survey in 2011 showed a huge variation between brands. The sodium content of the bread with the highest value was 350% higher than that of the lowest.26 Further reductions in the salt content of bread alone would have a major effect on salt intake.

Health Benefits of Reducing Salt Intake in Children
A reduction in the salt content of manufactured foods would lead to a reduction in salt intake in children. A meta-analysis of 10 controlled trials demonstrated that a reduction in salt intake by 42% in children resulted in a fall in BP of 1.17/1.29 mm Hg.27 A more recent study showed a similar magnitude of association.28 Although, this effect might seem small, from a population viewpoint, a 1- to 2-mm Hg reduction in BP during childhood could translate to a large reduction in the number of cardiovascular disease events in the future.1 Furthermore, a reduction in salt intake could lead to other positive health related outcomes.28 Studies have shown an association between salt intake and total fluid consumption, as well as sugar-sweetened soft drink consumption. A reduction in salt intake by reducing soft drink consumption could possibly play a role in helping to reduce childhood obesity.29,30

Perspectives
This is the first study in the United Kingdom that has measured salt intake in a large group of school children using the gold standard method, 24-hour urine collections. The study demonstrates that salt intake in children is still high, despite the implementation of a nationwide salt reduction strategy, and further reductions in manufactured foods are required. Because bread is the single largest contributor of salt in children’s diets, further reductions in the salt content of bread would have a significant effect on salt intake and should continue to be a leading focus in the UK’s salt reduction strategy. In addition, our study has demonstrated that it is feasible to collect 24-hour urine samples in children. Because the study was conducted in South London, it would be appropriate to apply this study in a nationally representative sample of children to determine salt intake at the population level. Furthermore, monitoring salt intake by 24-hour urine collections would be required to track the progress and effectiveness of salt reduction efforts. This will help reduce the rise in BP observed with age and, therefore, reduce the number of cardiovascular disease events in the future.

Acknowledgments
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References

Novelty and Significance

What Is New?
1. This is the first study in the United Kingdom that has measured salt intake in a large group of school children using 24-hour urinary sodium excretion.

What Is Relevant?
1. It is important to start interventions to lower blood pressure levels in children and to prevent the rise in blood pressure with age.
2. Studies investigating the role of salt intake in blood pressure in children demonstrate that a reduction in salt intake lowers blood pressure.

However, there are no reliable data on how much salt children are consuming.

Summary
This study has shown that salt intake is high in children and adolescents, despite a national salt reduction campaign. Because the majority of salt in children’s diets comes from processed foods, further effort is required to lower salt intake in manufactured foods.
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SALT INTAKE OF CHILDREN AND ADOLESCENTS IN SOUTH LONDON:
CONSUMPTION LEVELS AND DIETARY SOURCES

Naomi M Marrero a, Feng J He b, Peter Whincup c, Graham A MacGregor b

a Cardiovascular Sciences, St. George’s, University of London, UK
b Wolfson Institute of Preventive Medicine, Barts and The London School of Medicine & Dentistry, Queen Mary University of London, UK
c Division of Population Health Sciences and Education, St. George’s, University of London, UK

SUBJECTS AND METHODS

We carried out a cross-sectional study to determine the salt intake of children within 3 age tiers, i.e. young (5-6 year olds), intermediate (8-9 year olds), and adolescents (13-17 year olds). The study was carried out between October 2007 and June 2010.

Figure 1 illustrates the recruitment of participants into the study. Participants were mainly recruited from schools within the London Boroughs of Wandsworth, Sutton and Merton. Head teachers from randomly selected primary and secondary schools were contacted via an invitation letter and a phone call to request their school’s participation in the study. Additionally, St. George’s University of London (SGUL) ran a Spring School to educate teenagers (14-15 years old) from London schools about careers in healthcare. Attendees of the Spring School were also invited to participate in the study.

Information packs, including an invitation letter and a written consent form were sent to the parent or guardian of children in Reception year or Year 1 for the 5-6 year olds, Year 4 for the 8-9 year olds, and in the Year group/classes that the school considered most appropriate for the 13-17 year age group. Additionally, all of the children, except for the 5-6 year olds who were invited to take part during the school holidays, were given a presentation about the importance of the study and what it measures.

The study was approved by the Royal Marsden Research Ethics Committee. Written consent was obtained from the parent/caregiver as well as children aged ≥ 8 years.

Data Collection

Participants either carried out the urine collection and photographic diary on a school day, on a weekend day during the school-term or on a day during the school holidays. All of the 5-6 year olds did the urine collection and diet diary
on either the weekend or during the school holidays as parental supervision and assistance were required. For the 8-9 and 13-17 year olds initially participants were requested to participate on a school day, however, to try and improve the response rate participants were given a choice over whether they conducted the data collection on either a school day or one day over the weekend. In some schools, to reduce the requirements from the school, participants were requested to do the data collection on either a weekend day or one day during the school holidays.

24-hour urine collection
All children who entered the study were asked to complete a 24-hour urine collection. They were told not to change any dietary habits during the data collection period. A member of the research team gave verbal instructions to each participant on how to complete the urine collection. Participants were also given written instructions to keep with them, which included pictures to illustrate the collection procedure. Additionally, a member of the research team spoke with a parent of each participant in the 5-6 year old group. At the start of the collection procedure participants were instructed to empty their bladder and discard the urine. From that point onwards they collected all urine passed into a 2.5L or 5L container. The last time urine was passed into the container was 24 hours from the time they discarded their urine. It was reinforced to participants about the importance of ensuring that all of their urine for the duration of the 24 hours went into the container provided, and if they were going out to take either the container with them or an empty water bottle, in case they needed to urinate. If the participant did forget to collect his/her urine into the container during the 24-hour period, they were asked to record this on the container. Additionally, participants were questioned by research staff upon return of the collection bottle about the completeness of the collection. Participants were asked to record the start time and finish time of the collection on the container. Research staff oversaw the start and finish time of collections that were completed on a school day.

Urinalyses
The urines were measured for 24-hour urine volume, sodium, potassium, and creatinine.

Urinary sodium and potassium were measured using indirect ion-selective electrodes. Initially urinary creatinine was measured using the Jaffe method, however mid-way through the study the machines were replaced and in the later stages the enzymatic assay method was used.

Collections were deemed incomplete if the participant admitted to have missed at least one urine collection or if they had a 24-hour urinary creatinine of $< 0.1 \text{mmol/kg/d}^1$ and/or they had a reduced urine output of less than $0.5 \text{ml/kg/h}$ for the 5-6 and 8-9 year olds or less than $500 \text{mL/24-hour}$ for the 13-17 year olds$^2$. Urines were also deemed incomplete if the timing of the collection was less than 20 hours or greater than 28 hours.
Maximum salt intake recommendations
Children’s salt intake was compared against maximum salt intake recommendations. Although guidelines do exist in the UK for children and adults, unlike the recommendation for adults, the children’s recommendations are not based on reliable data. Therefore, new maximum recommendations were calculated for each age group. These recommendations are based on the Scientific Advisory Committee on Nutrition (SACN) recommendation for adults of 6g/day which has been adjusted downwards based on the average body surface area (BSA) of children relative to those of adults (Table 1). BSA was calculated from height and weight data obtained from the National Diet and Nutrition Survey (NDNS) rolling survey. The formula used was $\sqrt{\frac{\text{wt (kg)} \times \text{ht (cm)}}{3600}}$. From these calculations we propose the following maximum daily salt intake recommendations for children: 2g for 3-4 year old children; 3g for 5-8 year old children; 4g for 9-11 year old children; 5g for 12-15 year old children and 6g for children aged 16 years and over.

Dietary record
A photographic food diary was completed either the day before, or on the day of the urine collection. Participants and the parent of the 5-6 year olds were given verbal instructions on how to keep a photographic food record. Detailed written instructions were also given to each child to take home. Each participant was provided with a digital camera, and instructed to photograph everything he/she consumed for a complete day. The participants were requested to place a 15cm ruler next to the plate, food item etc and asked to photograph food and drink both before and after consumption. The parent or child also kept a dietary record of the food and drinks consumed. Participants were requested to record in as much detail as possible information about the items consumed. Details of recipes used, including ingredients, were requested as well as brand names of products, cooking methods, and portion sizes using household measures. Foods eaten away from home were also recorded. If a dietary record had not been completed the researchers would complete one with the child and/or parent when the participant returned the cameras. The photographs were used as an aid to assist this.

Dietary analysis
All dietary information was entered into a nutrient analysis software program, WISP (Weighed Intake Software Package), which uses McCance and Widdowson’s food tables and published supplements to generate food composition data. WISP allows new foods and drinks, which are not already in the program, to be added. The nutritional information for these foods was taken from product labels or company websites. Recipes provided by the participants were also added to WISP. In total 866 new food codes were added to the program.

Portion sizes were estimated by comparing the food photographs taken to photos in the photographic food atlas. Manufacturer’s data, and fast food portion sizes were also used to assess portion size. If the participant had not taken a photo of a food/drink item consumed then the household measure recorded in the diet diary or standard portion sizes provided in WISP were used to estimate portion size.
All of the diet diaries were entered into WISP, by one nutritionist in order to reduce variation due to data entry. After all the data entry was completed, each diet diary entry was re-checked, after a period of at least 2 months from the initial entry, by the same nutritionist.

Food codes used were categorized into 18 major food groups and the contribution of these 18 food groups to salt intake was calculated.

**Anthropometric measurements**
Height was measured to the nearest 0.1cm. Weight was measured to the nearest 0.1kg.

Additionally, the parent of the child or the child was requested to complete a questionnaire providing background information on the child, including date of birth and sex.

**Statistical analysis**
Data are reported as mean±SE, 95% CIs or as a percentage, where appropriate. One-way ANOVA was used to compare the 3 age groups for continuous data. Independent samples t-test was used to compare boys with girls within each age group for continuous data. The percentages of children above the maximum salt intake recommendations are reported. All statistical analyses were performed using SPSS.

**References**
Supplementary Table 1. Demographics of study participants by age and sex

<table>
<thead>
<tr>
<th></th>
<th>All n=338</th>
<th>Males n=177</th>
<th>Females n=161</th>
<th>5-6 yr olds</th>
<th>Males n=125</th>
<th>Females n=60</th>
<th>8-9 yr olds</th>
<th>Males n=56</th>
<th>Females n=55</th>
<th>13-17 yr olds</th>
<th>Males n=60</th>
<th>Females n=46</th>
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<td>9.54 ±.05</td>
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<td>5.69 ±.07</td>
<td>5.63</td>
<td>5.07 ±.07</td>
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<td><strong>Weight (kg)</strong></td>
<td>37.19 ±1.02</td>
<td>39.19 ±1.46</td>
<td>40.82 ±1.42</td>
<td>36.35 ±1.46</td>
<td>22.18 ±.34</td>
<td>21.50 ±.34</td>
<td>22.54 ±.34</td>
<td>21.62 ±.34</td>
<td>21.80 ±.34</td>
<td>20.77 ±.51</td>
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<td><strong>Height (cm)</strong></td>
<td>138.30 ±1.15</td>
<td>136.04 ±1.68</td>
<td>140.34 ±1.55</td>
<td>136.10 ±1.55</td>
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<td>119.44 ±.77</td>
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<td><strong>8-9 yr olds</strong></td>
<td>All n=111</td>
<td>Males n=56</td>
<td>Females n=55</td>
<td>All n=102</td>
<td>Males n=56</td>
<td>Females n=46</td>
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<td><strong>Age</strong></td>
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<td>8.37 ±.10</td>
<td>14.32 ±.13</td>
<td>14.09 ±.13</td>
<td>13.82 ±.21</td>
<td>15.17 ±.21</td>
<td>14.76 ±.59</td>
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<td><strong>Weight (kg)</strong></td>
<td>31.38 ±.65</td>
<td>30.09 ±.74</td>
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<tr>
<td><strong>Height (cm)</strong></td>
<td>133.97 ±.66</td>
<td>132.66 ±.78</td>
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<td>133.59 ±1.09</td>
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**Supplementary Table 2.** 24-hour urine volume and potassium levels by age and sex

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<tr>
<th>Age Group</th>
<th>All</th>
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<th>All</th>
<th>Females</th>
<th>Males</th>
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<td>n=61</td>
<td>n=65</td>
<td>n=111</td>
<td>n=55</td>
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<tr>
<td></td>
<td>Mean ± SE CI</td>
<td>Mean ± SE CI</td>
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<tr>
<td>5-6 year olds</td>
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<tr>
<td>Volume</td>
<td>650±30 to 709</td>
<td>628±42 to 711</td>
<td>671±42 to 755</td>
<td>802±33 to 867</td>
<td>779±41 to 861</td>
<td>824±51 to 927</td>
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<td>Potassium</td>
<td>37.31±1.34 to 34.66 to 31.10 to 35.88 to 46.16±1.70 to 41.79±2.21</td>
<td>35.38±2.14 to 39.11±1.62 to 35.88±1.70 to 42.78±2.21</td>
<td>39.11±1.62 to 42.35±2.21</td>
<td>46.16±1.70 to 49.53±2.21</td>
<td>41.79±2.21 to 46.22±2.21</td>
<td>46.16±1.70 to 55.41±2.48</td>
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<tr>
<td>8-9 year olds</td>
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<tr>
<td>Volume</td>
<td>1091±43 to 1177</td>
<td>1004±52 to 900 to 1108</td>
<td>1162±65 to 1291</td>
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<td>Potassium</td>
<td>57.87±1.93 to 54.05 to 47.71 to 62.54±2.88</td>
<td>52.09±2.17 to 56.47 to 56.76</td>
<td>57.87±1.93 to 52.09±2.17</td>
<td>47.71±2.17</td>
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<td>13-17 year olds</td>
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*Mean* values are given with 95% confidence intervals (CI).