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ORIGINAL CONTRIBUTION

Elevated urinary Na/K ratio among Lebanese elementary school children is attributable to low K intake

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Abstract
Purpose To estimate total sodium (Na) and potassium (K) intake using non-fasting morning urine specimens among Lebanese elementary (6–10 year old) schoolchildren.
Method A national cross-sectional study was conducted. A multistage cluster sampling procedure was used to select a representative sample of 1403 healthy children from the eight districts of Lebanon. Age, anthropometric measurements, and urine samples were collected and analyzed for Na, K, and creatinine (Cr).
Results The ratios of Na and K to Cr were 23.93 ± 15.54 mM/mM (4.86 ± 3.16 mg/mg) and 11.48 ± 5.82 mM/mM (3.97 ± 2.01 mg/mg), respectively, and showed differences (P value <0.001) between age groups. No differences were found between boys and girls in all the measured Na and K parameters. The estimated mean Na intake was 96.57 ± 61.67 mM/day (2.220 ± 1.418 g/day or 5.69 ± 3.64 g NaCl/day) and exceeded the upper limit of intake in half the children. Estimated K intake was 46.6 ± 23.02 mM/day (1.822 ± 0.900 g/day), and almost all children failed to meet the recommended daily K intake. The high Na/K ratio (2.361 ± 1.67 mM/mM or 1.39 ± 0.98 mg/mg) resulted from a combination of high Na and low K intake but was mostly affected by K intake.
Conclusions About 50 % of children exceeded the recommended daily upper intake for Na, while the majority was below K adequate intake. This unfavorable Na/K ratio is indicative of potentially negative health effects at later stages in life. Interventions aimed at reducing salt intake and increasing consumption of fruits and vegetables are warranted.

Keywords Lebanese children · Potassium intake · Sodium intake · Urinary potassium-to-creatinine ratio · Urinary sodium-to-creatinine ratio

Carla El Mallah and Karina Merhi have contributed equally to the work, and the first listed authors made the greatest contribution to the paper.

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Introduction

Sodium (Na) and potassium (K) are two essential electrolytes for growth and development of children. Na is the principal cation of extracellular fluid, while K is the most abundant in the intracellular space. Together they play a vital role in the regulation of body fluids, acid–base balance, and osmotic equilibrium through the Na–K pump activity. Additionally, Na and K concentrations determine membrane potentials in nerves and muscles, promote cellular growth, and regulate active transport of molecules across cell membranes [1]. In normal conditions, even under a Na-restricted diet, Na deficiency does not occur [2]. In contrast, excessive Na consumption has frequently been reported with high Na intakes being primarily attributed to excessive consumption of processed foods [3, 4]. Observational and interventional studies have revealed a positive association between Na intake and increased risk of hypertension [5], cardiovascular diseases [6], kidney problems [7], cancers [8], etc. Salt intake has also been linked to increased thirst [9] which triggers high-energy sugar-sweetened beverages consumption and consequently increases risk of obesity [10, 11], especially among children and adolescents. Conversely, adequate intakes of K have been reported to protect against CVDs [12] with some authors attributing a greater importance of Na/K ratios in the determination of CVD risks [13].

Although non-communicable diseases (NCDs) are more common in adulthood, their risk factors are increasingly prevalent in younger populations [14]. Evidence suggests that the development of CVDs and other NCDs in adulthood begins during childhood [15]; consequently, the presence of the risk factors of these diseases in childhood is likely to predict later risks [5]. Direct causative effect of excessive dietary Na in the development of CVDs in children has not been firmly established [16]; however, it is generally accepted that limiting Na intake, as well as increasing K consumption, protects against their development.

High Na intake is known to increase risk of hypertension and consequently CVD and mortality, through alteration of renin–angiotensin–aldosterone system and activation of pressure-natriuresis mechanism [9]. However, high K intake is reported to blunt the harmful effect of Na [17], where comes the importance of a balanced Na/K ratio. In Lebanon, the high prevalence of hypertension (23.1 %) [18] and CVDs was reported to be the leading causes of mortality (47 %) [19]. Thus, it is essential to target all related modifiable risk factors from early childhood [11] as a public health strategy to reduce NCDs. This would require better understanding of Na and K intake among population.

Accurate determinations of Na and K intakes are difficult to obtain with dietary assessment methods [20]. The reliability of these methods in the assessment of Na and K has been questioned [21] especially as they depend on a number of factors (estimation, matching, categorization, memory, etc.) that demand high levels of commitment and rely on subjective judgments; these limitations become more pronounced when dietary assessment methods are used in children. Furthermore, the determination of salt intake by dietary methods usually underestimates dietary Na because it does not account for added salt. Twenty-four-hour urine collection is the gold standard to assess dietary Na and K intake [1, 20, 22] because total urinary electrolyte excretion matches intake in normal conditions. However, this method is cumbersome in population studies involving a large number of children [23]; therefore, other alternatives were being used. Attempts to calculate 24-h Na and K excretion using spot urine Na/Cr and K/Cr ratios are well documented and reveal good approximations, especially when using second morning voiding urine specimens [24, 25] which were shown to provide a better estimate when compared to casual urine samples.

No data about Na and K excretion are available for the Lebanese young population. Therefore, this study aimed at determining urinary Na/K ratio and predicting 24-h Na and K excretion as an indirect reflection of intakes among Lebanese schoolchildren aged 6–10 years. These findings would then be used to plan for appropriate public health and dietary interventions.

Materials and methods

Study population

A cross-sectional study was carried out between March 2013 and January 2014 [26]. A total of 1403 (781 boys and 622 girls) healthy elementary students (6–10.9 years) were randomly selected from 26 schools, using a multistage cluster sampling procedure. School-based sampling was used due to high enrollment rate in Lebanese elementary children (96 % in 2012). Schools were randomly selected from a comprehensive listing in proportion to the national distribution of schools by administrative district and school type (private, private-free, or public). Selected schools were then visited, and consent forms were sent to parents. Parents who consented were asked to fill a health questionnaire, and children having chronic or acute illnesses or receiving any medical treatments were excluded from the study. In a follow-up visit, assent was obtained from children, and height and weight of the children were measured using standard procedures. Urine samples were collected between 9:00 a.m. and 1:00 p.m. which corresponded to the second morning voiding urine specimens, and aliquots were stored at −20 °C until analyzed.

The study protocol was approved by the Institutional Review Board (IRB) of the American University of Beirut, and recruitment was coordinated with the Ministry of Education and Higher Education.

Analysis of sodium, potassium, and creatinine

Urine samples were defrosted and centrifuged. Na and K concentrations were measured by direct potentiometry, and Cr was simultaneously determined using the two-point rate procedure using VITROS 350 analyzer (Ortho Clinical Diagnostics, Johnson and Johnson, Buckinghamshire, UK).

Estimations of 24-h sodium, potassium, and creatinine

Estimation of daily urinary electrolyte excretion from electrolyte to Cr ratio in spot urine samples was reported to depend on the accuracy of predicting urinary 24-h Cr [27]. In our study, total (24-h) Cr excretion was based on the data of Remer et al. [28] in which children's height has been reported to be highly correlated with 24-h Cr excretion ($R^2 = 0.87$ and P value <0.0001). The fact that our estimated 24-h Cr results were comparable to others [29] lends further support to Remer's equation [28] and to the validity of the estimated electrolytes (Na and K).

The estimation of Na and K intakes was calculated using the following strategy:

1. Spot urine Na (SUNa), K (SUK), and Cr (SUCr) were measured.
2. Creatinine excretion per 24 h (Pred 24 h Cr) was calculated using the equation of Remer et al. [28] derived from data on 3- to 18-year-old children.
3. Predicted 24-h Na (Pred 24 h Na) and K (Pred 24 h K) excretions were then calculated using the following equations:

$$\text{Pred 24 h Na} = \frac{\text{SUNa}}{\text{SUCr}} \times \text{Pred 24 h Cr} \quad \text{and}$$

$$\text{Pred 24 h K} = \frac{\text{SUK}}{\text{SUCr}} \times \text{Pred 24 h Cr}$$

The Pred 24-h Na and K excretion were assumed to reflect 24-h Na and K intakes, respectively. Consequently, this paper will refer to "estimated Na intake" and "estimated K intake."

4. Salt equivalents were calculated by dividing Na concentrations (in mg) by 390.

Statistical analysis

Statistical analysis was performed using SPSS 21 (IBM SPSS). Statistical significance was set at P value <0.05. Results are presented as mean ± standard deviation. Frequencies and descriptive statistics were performed for the different variables. Data were stratified by gender or by five age groups (6–6.9, 7–7.9, 8–8.9, 9–9.9 and 10–10.9 years). Additionally, age was classified in two categories based on the recommendations of the Institute of Medicine [1] (6–8.9 years in one age category and 9 and 10 years in another).

Two-sample t test was used to analyze differences by gender and one-way ANOVA to evaluate differences among age groups. Subgroup analyses (differences among the five age groups) were analyzed using Fisher's test. Three subjects (outliers) were excluded based on the Anderson–Darling normality test.

Results

A total of 1400 children (780 boys and 620 girls) were recruited. Children's anthropometric measurements are outlined in Table 1. Boys and girls, with a ratio of 1.3:1, had similar weights and BMI, but girls were marginally taller than boys (P value = 0.049).

Total urinary Na/Cr ratio was 23.93 ± 15.54 mM/mM (4.86 ± 3.16 mg/mg) and did not differ between boys and girls (P value = 0.689; Table 2), but was found to significantly decreased with age (P value <0.001) (Supplemental Table). Estimated Na intake was 96.57 ± 61.67 mM/day (2.220 ± 1.418 g/day) and was comparable between boys and girls (P value = 0.438) and between the different age groups (P value = 0.319).

Total urinary K/Cr ratio was 11.48 ± 5.82 mM/mM (3.97 ± 2.01 mg/mg), and no differences were observed between boys and girls (P value = 0.233), but the ratio decreased with age (P value <0.001). The estimated K intake 46.6 ± 23.02 mM/day (1.822 ± 0.900 g/day) was similar between genders (P value = 0.067) and showed a

Table 1 Anthropometric measurements of the sample population

Measure	Total (1400)	Boys (780)	Girls (620)	P value
Weight (kg)	28.31 ± 7.88	28.12 ± 7.73	28.56 ± 8.06	0.299
Height (cm)	127.1 ± 9.7	126.6 ± 9.4	127.7 ± 10.1	0.049
BMI (kg/m^2)	17.25 ± 2.75	17.28 ± 2.81	17.22 ± 2.67	0.710

All values are reported as mean ± SD

The numbers presented between brackets is the sample size

t test is used to compare boys and girls, and significance is set at P value <0.05

Table 2 Na and K urinary excretions and estimated intakes of elementary Lebanese schoolchildren

Measures	Total (1400)	Boys (780)	Girls (620)	*P* value
Sodium				
Urinary Na/Cr (mM/mM)	23.93 ± 15.54	23.8 ± 15.50	24.10 ± 15.6	0.689
Urinary Na/Cr (mg/mg)	4.86 ± 3.16	4.84 ± 3.15	4.90 ± 3.17	
Estimated Na intake (mM/day)	96.57 ± 61.67	95.43 ± 62.75	98.00 ± 60.31	0.438
Estimated Na intake (g/day)	2.22 ± 1.42	2.19 ± 1.44	2.25 ± 1.39	
Potassium				
Urinary K/Cr (mM/mM)	11.48 ± 5.82	11.32 ± 5.71	11.69 ± 5.95	0.233
Urinary K/Cr (mg/mg)	3.97 ± 2.01	3.91 ± 1.97	4.04 ± 2.06	
Estimated K intake (mM/day)	46.6 ± 23.02	45.60 ± 22.99	47.87 ± 23.00	0.067
Estimated K intake (g/day)	1.82 ± 0.90	1.78 ± 0.90	1.87 ± 0.90	
Urinary Na/K (mM/mM)	2.36 ± 1.67	2.33 ± 1.58	2.37 ± 1.66	0.713
Urinary Na/K (mg/mg)	1.39 ± 0.98	1.37 ± 0.93	1.39 ± 0.98	
Salt equivalent (g/day)	5.69 ± 3.64	5.63 ± 3.70	5.78 ± 3.55	0.438

All values are reported as mean ± SD

The numbers presented between brackets is the sample size

t test is used to compare boys and girls, and significance is set at *P* value <0.05

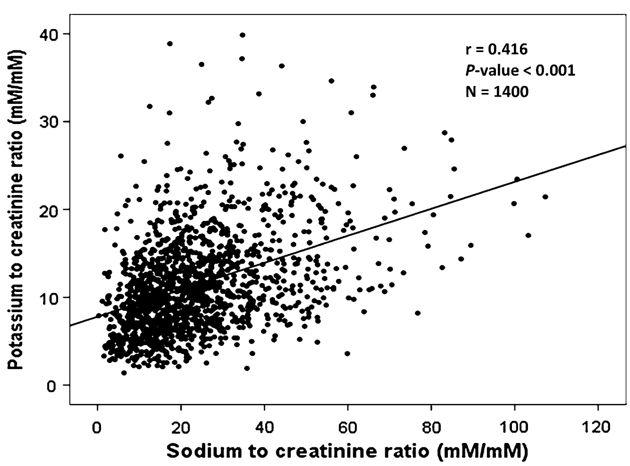

Fig. 1 Relationship between urinary Na/Cr and K/Cr ratios of elementary Lebanese schoolchildren

significant increase with age (*P* value <0.001). The urinary Na/K ratio 2.36 ± 1.67 mM/mM (1.39 ± 0.98 mg/mg) was similar between genders and the different age groups (*P* value >0.05). In addition, a significant, but weak positive correlation was found between urinary Na/Cr and K/Cr ratios (Fig. 1). Salt intake (salt equivalent) of the sample population was found to be 5.69 ± 3.64 g/day, and this was similar between boys and girls as well as between the different age groups (*P* value >0.05).

The dietary reference intakes of Na and K varied according to the different age categories (e.g., 4–8 and 9–13 years) [1]. In our study, 49.7 % of the children (486 children) in the age group 6–8.9 years exceeded the upper limit (UL) of Na intake and 97.8 % (957 children) were below the adequate intake (AI) of K. In the age group 9–10.9 years, 44.1 % of children (186 children) were above the UL for Na and 97.9 % (412 children) were below the recommended intake of K. The population distribution presented as median and interquartile range of Na and K intake is illustrated in comparison with recommended intakes in Fig. 2.

Discussion

Globally, increases in salt intake have reached epidemic levels. In virtually all published data, population consumption of Na has been reported to far exceed physiological needs [20]. Most children consume more Na than is recommended (1.2 g or 53 mM/day for 4- to 8-year-old children and 1.5 g or 65 mM/day for older children), sometimes exceeding the UL of intake (1.9 g or 83 mM/day for 4- to 8-year-old children and 2.2 g or 95 mM for older children) [1]. In contrast, the majority of children ingest less K than the recommended levels (3.8 g or 97 mM/day for 4- to 8-year-old children and 4.5 g or 115 mM/day for older children) [1].

Within this framework, population-based strategies to reduce salt/Na intake are being implemented in different countries with the aim of decreasing a potential risk factor of CVDs (especially hypertension), a leading cause of morbidity and mortality in Lebanon as well as globally. Most "salt-reduction" interventions target adults; however, introducing salt-reduction practices in early childhood has been shown to yield concrete and long-term benefits because food preferences and dietary habits in childhood influence lifetime food patterns, and high Na intake along with low K intake in childhood has been shown to be

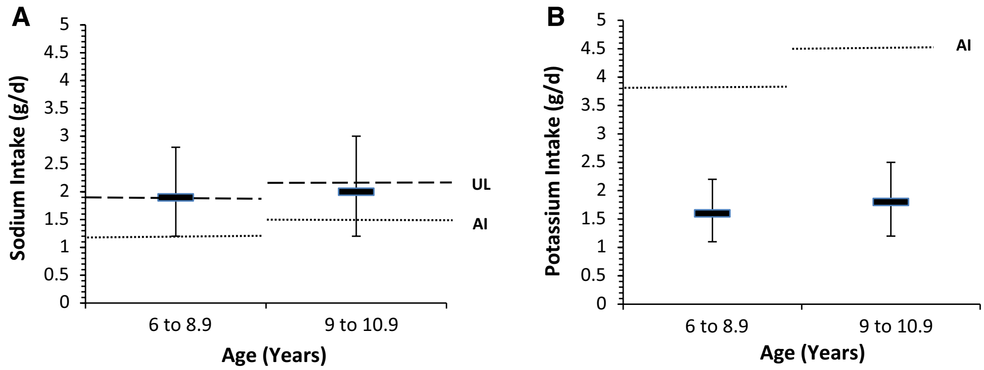

Fig. 2 Median and interquartile (25th and 75th percentiles) estimated sodium (**a**) and potassium (**b**) intake compared with dietary reference intakes (IOM, 2005) by age group of elementary Lebanese schoolchildren. Normal intake ranges between the adequate intake (AI) and the upper limit of intake (UL). AI of Na is 1.2 g/day (53 mM)/day for 4- to 8-year-old children and 1.5 g/day (65 mM)/day for older children. AI of K is 3.8 g (97 mM)/day for 4–8 years and 4.5 g (115 mM)/day for 9 and 10. UL of Na is 1.9 g/day (83 mM/day) for 4- to 8-year-old children and 2.2 g/day (95 mM/day) for older children. No evidence that high K intakes from food have adverse effect in healthy individuals → no UL for K

independent risk factors for chronic diseases in adulthood [13, 30].

Despite efforts to reduce its intake, Na around the world remains excessively highly consumed [31]. Additionally, a new dietary trend shifts K intake, especially among Mediterranean populations, from high to low which increases risks of CVDs.

Lebanese children consumed an average of around 96.57 ± 61.67 mM/day (2.220 ± 1.418 g/day) of Na, 1.5- to twofold the AI and 46.6 ± 23.02 mM/day (1.822 ± 0.900 g/day) of K, about half to one-third the AI. Na intake in around half the children exceeded the UL and K intake in almost the whole sample was below the recommendations.

In line with our results, using different methods of assessment (urine-based and dietary assessment method), high Na and low K intakes were also described in other Mediterranean countries, highlighting an alarming regional dietary trend. Electrolytes assessment showed that, in Spain [32], children consumed around 132.7 ± 51.4 mM/day of Na (equivalent to 7.8 g of salt) and 49.4 ± 15.8 mM of K and ratios Na/Cr and K/Cr were 0.19 ± 0.06 mM/mg (4.37 ± 1.38 mg/mg) and 0.07 ± 0.02 mM/mg (2.73 ± 0.78 mg/mg), respectively. Another study on Spanish 6- to 14-year-old children reported an intake of 136.3 ± 63.3 mM/day of Na and 39.2 ± 15.5 mM/day of K [16]. Similar findings were also described in two studies on Italian children [33, 34] where Na intake varied between 117 and 129 mM/day and K intake between 36 and 43.5 mM/day. Lower intakes yet very high ratios for both minerals were described among Iranian children [35, 36]. Same trend was observed among French children who had on average 103 mM/day of Na and 64 mM/day of K [37]. The mean Na intake among young Greek (1.481 g/day) was lower than what we found in Lebanon, however still considered high [38].

The Mediterranean diet, traditionally adopted by the Lebanese people, is relatively high in Na [38]. The average Na intake of Mediterranean populations is lower than the amount of Na contained in typical Western (3.271 g/day for American [39] and 3.412 g/day for Canadian [40]) or far Eastern (≈10 g/day for Japanese [41]) diets despite the fact that large percentage of children are shifting their diets and having low adherence to Mediterranean diet [38].

Additionally, dietary Na sources are known to vary among different populations and it is well documented that processed foods contribute at least 75 % of total Na intake [3, 39] with bread, cereals, and grains accounting for 19.5 % of Na in a typical American diet [42]. Similar sources of Na in the Mediterranean diet [38] and the Lebanese diet [43] have been also reported. In effect, the high levels of Na in the Mediterranean diet traditionally consumed in Lebanon have been compounded by the more recent adoption of Western diets. At the same time, the weak correlation between Na and K excretions ($R^2 = 0.17$) implies that these electrolytes were predominantly not derived from the same food sources (salted crackers, nuts, seeds, etc.), which points to a reduction in the intake fruits and vegetables that are known to have high K levels.

High Na intake in Lebanon could be attributed, at least in part, to attitudes and knowledge of the population; in one study, less than half of subjects considered salt intake to be of concern to health, only 22.6 % of subjects knew that processed foods were the major sources of Na in the diet, and 38.6 % sought low-Na foods [44].

Additionally, we found that not only due to high Na intake but also low K intake, urinary Na/K ratio was four times higher than the ratio (0.546 mM/mM) calculated from the recommended intakes and almost double the ratio suggested by the WHO (~1 mM/mM) [45]. This ratio has been reported to be high in most populations [16, 32–34, 37, 46, 47], highlighting an alarming worldwide health concern. Low K intake is believed to cause electrolyte imbalance and to exacerbate the deleterious effects of high intakes of Na. The low K intake has been attributed to a low consumption of fruits and vegetables [47–49] which is very surprising among Lebanese schoolchildren because fruits and vegetables are grown locally and are available, at affordable prices, all year round. Recommendations in this concern emphasize the importance of increasing sources of K, especially fruits and vegetables [50], and this has been already detected as a main cause of misbalanced Na/K ratio among Lebanese children.

Na and K consumption did not differ between boys and girls, and this was supported by Safarinejad [35] who studied Na/Cr and K/Cr ratios. However, higher Na consumption in boys was also reported [13, 16] and was attributed to higher energy intake [51], since, when corrected for energy, these differences were no longer significant.

The latter interpretation is also plausible for age group differences seen, since older children are expected to have higher energy intakes and thus to consume higher amounts of Na and K. Na/K ratio did not differ with age which shows that, despite significant difference in K intake with age, the overall dietary habits and food patterns had barely changed.

To our knowledge, urine has not been previously used to assess Na and K intake in Lebanon. However, estimated Na intake in adults obtained from dietary assessment method was 3.13 g/day [31], and this may underline the fact that food preferences are built in childhood and when energy intake increases with age higher Na intake is yielded.

This is the first study that provides data on Na and K excretion in a sample of healthy Lebanese children. The main limitation of this study is that 24-h mineral excretion was estimated from Na/Cr and K/Cr in spot urines (second morning void), though this method has only been validated in adults and not in children.

In conclusion, poor dietary habits favoring high Na and low K intake are being adopted in childhood, thereby predisposing the Lebanese population to the development of NCDs later in life. The widely held anecdotal belief that the Lebanese population has adequate intake of K in view of the availability and affordability of locally produced fruits, vegetables, and legumes is not supported by the findings of the present work. A multidisciplinary approach involving policy makers, media, and food industries is needed to develop and implement measures for reducing Na levels in foods. The present study highlights the need for policies to reduce Na content of commonly consumed foods along with awareness-raising on the importance of reducing salt intake and increasing consumption of fruits and vegetables. It will be important to target some of these policies and awareness campaigns in schools to begin to reduce Na intake in children. This should be paired with policies to increase fruit and vegetable availability in schools and to promote their intake in childhood, a critical period for the development of food preferences and eating habits.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent All subjects gave their informed consent prior to their inclusion in the study.

Ethical approval The study protocol was approved by the Institutional Review Board of the American University of Beirut.

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