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Short Communication

Highlighting the ratio of sodium to potassium in population-level dietary assessments: cross-sectional data from New York City, USA

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Abstract
Objective: To contrast mean values of Na:K with Na and K mean intakes by demographic factors, and to calculate the prevalence of New York City (NYC) adults meeting the WHO guideline for optimal Na:K (<1 mmol/mmol, i.e. <0·59 mg/mg) using 24 h urinary values.
Design: Data were from the 2010 Community Health Survey Heart Follow-Up Study, a population-based, representative study including data from 24 h urine collections.
Setting: Participants were interviewed using a dual-frame sample design consisting of random-digit dial telephone exchanges that cover NYC. Data were weighted to be representative of NYC adults as a whole.
Subjects: The final sample of 1656 adults provided 24 h urine collections and self-reported health data.
Results: Mean Na:K in NYC adults was 1·7 mg/mg. Elevated Na:K was observed in young, minority, low-education and high-poverty adults. Only 5·2 % of NYC adults had Na:K in the optimal range.
Conclusions: Na intake is high and K intake is low in NYC adults, leading to high Na:K. Na:K is a useful marker and its inclusion for nutrition surveillance in populations, in addition to Na and K intakes, is indicated.

Keywords
Sodium
Potassium
Surveillance

High Na intake and low K intake are independently associated with an increased risk of developing high blood pressure[1,2]. To achieve dietary recommendations, most adults would need to decrease their Na intake and increase their K intake[3,4], resulting in a decreased Na:K. An elevated Na:K is associated with higher blood pressure[5] and poor cardiovascular outcomes[6], and is attractive as a potential surveillance tool of population-level dietary habits. Although the USA has no formal recommendation for Na:K[7], the WHO defined an optimal Na:K as < 1·0 mmol/mmol (i.e. < 0·6 mg/mg)[8]. The objectives of the current analysis were to present mean urinary Na:K values from a population-based sample and to report the percentage of New Yorkers meeting the WHO-defined optimal Na:K.

Methods

Data were obtained from the New York City (NYC) Heart Follow-Up Study (HFUS), a cross-sectional study conducted in 2010 to assess Na intake in a population-based, representative sample of NYC adults aged 18 years and older. Detailed study information has been described in

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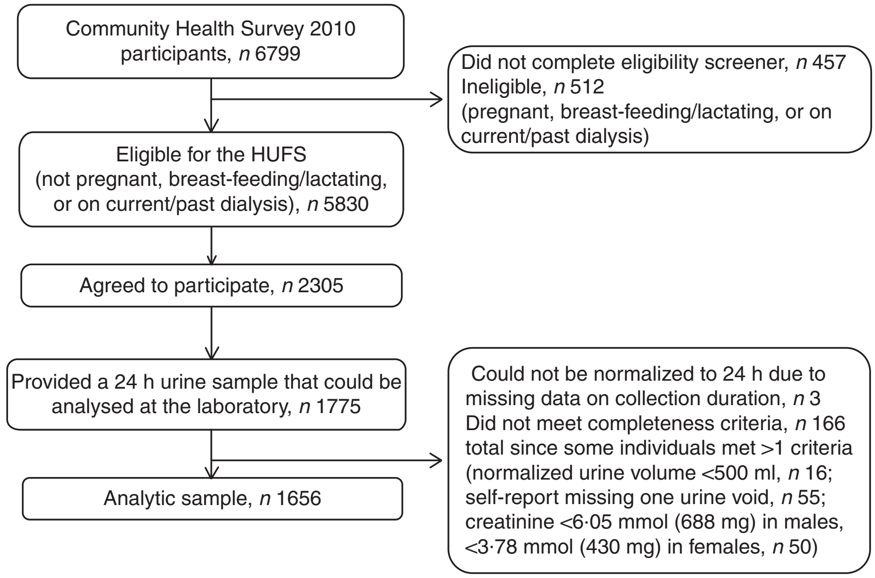

Fig. 1 Heart Follow-Up Study (HFUS): participant flow and response rates

a comprehensive Methods Report[9]. Study participants meeting the inclusion criteria were recruited from the Community Health Survey (CHS), an annual health survey conducted by the NYC Health Department. The CHS is designed after the national Behavioral Risk Factor Surveillance Survey (BRFSS) and includes questions either from national surveys or questions that have been validated by pre-testing in the NYC adult population. In 2010, more than 10 000 New Yorkers were interviewed using a dual-frame, stratified random sample design consisting of random-digit dial of landline and cellular telephone exchanges that cover NYC[10]. This recruitment design produces a sample that may be weighted to produce estimates that are representative of the NYC adult non-institutionalized population as a whole. Throughout the recruitment process, participation rates were closely monitored through daily and weekly reports by NYC Health Department survey staff.

Following the CHS questionnaire, participants meeting the three inclusion criteria (not pregnant, not breast-feeding or lactating, and not on current or past dialysis) were invited to participate in the HFUS. HFUS participants performed a 24 h urine collection; prior protocols were used as a basis for the design of the 24 h urine collection[11] but were modified to accommodate the unique needs of NYC and our study. Following the collection period, a home visit was scheduled with a medical technician. The home visit did not occur unless a signed informed consent was collected at the start of the visit. At the home visit, which followed a strict clinical protocol[12], an aliquot of the 24 h urine collection was collected. Two specimen tubes of aliquoted urine were included in case the first tube was damaged during shipment or the laboratory needed to redo the urinalysis. The urine samples were sent to a collaborating laboratory for the analysis of Na and K. The laboratory staff flagged any values that appeared to be incongruous with the volume of urine collected. No samples were flagged in this process. Results were sent via hard copy (laboratory values per participant) and via spreadsheet to the NYC Health Department, and were checked using double data entry from the original hard copy results. The Institutional Review Board of the NYC Health Department approved the study.

The 2010 CHS response rates were 17 % and 28 % for landline and cellular telephone exchanges, respectively. Cooperation rates among those who were reached were 77 % among landline contacts and 94 % among cellular contacts. Of the 2010 CHS participants screened for HFUS participation, 5830 eligible adults were identified. A total of 2305 agreed to provide a 24 h urine sample and of these, 1775 (30 %) provided a sample that could be analysed by the laboratory. The overall participant flow is displayed in Fig. 1. Those who agreed to participate were slightly more likely than those who did not to be Hispanic, <65 years of age, lower income and obese; however, there were no meaningful differences in self-reported high blood pressure or general health status between CHS and HFUS participants[9]. Incomplete samples were defined as those provided by participants who reported missing a collection and as those with a total urine volume < 500 ml or urine creatinine < 6·05 mmol creatinine in males and < 3·78 mmol creatinine in females (both being biologically implausible; Elliott P & Stamler J, personal communication, 2011). The final analytic sample size was 1656.

Measurement and definition of covariates

Na and K contents of 24 h urine samples were determined using the ion-selective electrode potentiometric method on the Roche DPP Modular analyser (Hoffman-La Roche, Ltd, USA). Laboratory values were normalized to a 24 h period prior to analysis. Results are presented in mg or mg/mg. BMI was calculated from measured weight in kilograms divided by the square of height in metres. Demographic (age, sex, race/ethnicity, poverty, education, nativity) and other characteristics (smoking, physical activity, fruit and vegetable intake, fast-food consumption, soda consumption) were either included in the CHS or in the questionnaire asked of only the subset of HFUS participants. Poverty was assessed as annual combined household income and was grouped according to federal poverty guidelines. Nativity (US-born *v.* foreign-born) was determined by asking state and country of birth. Because Na intake is related to diet, which in turn is heavily influenced by culture, those reporting being born in Puerto Rico or other US Territories were considered 'foreign-born'. Physical activity was assessed using the validated question, 'During the past 30 d, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?'. Fruit and vegetable intake was reported as servings/d and categorized (none, 1 to 4, 5+). Fast-food consumption was assessed as a continuous variable with the question, 'How often do you eat something from a fast-food restaurant or chain such as: McDonalds, KFC, Taco Bell, Golden Krust or similar places?', and was categorized as times/week (none, <1 (more than 0), 1 to <2, 2 to <3, 3 to <6). Per-day soda consumption was assessed as a continuous variable with the question, 'How often do you drink sugar sweetened soda? Do not include diet soda or seltzer', and categorized as a binary variable (two or more sodas daily, yes or no).

Statistical analysis

Differences in mean Na:K, Na intake and K intake by subgroups were assessed using *t* tests. The *P* trend across ordinal variable categories was assessed using Wald χ^2 tests. Multivariable linear regression models were used to understand factors associated with higher Na:K after adjustment for age, sex, race/ethnicity, poverty, education, nativity (foreign-born *v.* US-born), BMI, smoking status and physical activity. Comparisons of those with Na:K < 0·6 *v.* Na:K ≥ 0·6 by subgroup were assessed using χ^2 tests. Analyses were performed incorporating sampling weights to account for complex survey design and non-response. Data were analysed using the SUDAAN statistical software package version 10·0.

Results

The final sample of 1656 participants was weighted to be representative of the NYC population to estimate Na and K intakes in all NYC adults. Over 75 % of participants were between the ages of 25 and 64 years, and about half were male; half were Black or Hispanic; about half were foreign-born; 48 % had an income less than 200 % and 15 % had income between 200 and 399 % of the federal poverty level. The majority had less than a college education (69 %) and was US-born (58 %). The population was evenly distributed as normal weight, overweight and obese, and about 40 % were current or former smokers, 26 % were physically inactive over the past 30 d, 11 % reported no servings of fruits and vegetables the previous day, 49 % ate at a fast-food chain in the past week, and 10 % drank two or more sodas daily.

Mean Na:K in NYC adults was 1·7 mg/mg, with higher Na:K observed in: younger *v.* older adults; Black and Hispanic race/ethnic subgroups *v.* Whites; those with a higher *v.* a lower poverty level; those with a lower *v.* a higher educational attainment; US-born *v.* foreign-born; and obese *v.* normal BMI (Table 1). A higher Na:K was also associated with self-reported less healthy behaviours (high physical inactivity; low fruit and vegetable intake; high fast-food intake; and consumption of two or more sodas daily) compared with healthier behaviours. The observed patterns did not differ substantially in multivariable-adjusted analyses, but differences observed for poverty level and physical activity were no longer statistically significant (results not shown).

Only 5·2 % of New Yorkers had Na:K < 0·6 mg/mg. Being 45 years or older, White, engaging in healthier behaviours, having a higher income, having a college degree and being at a healthy weight were associated with Na:K < 0·6 mg/mg (data not shown).

Discussion

In adult NYC residents, the mean Na:K assessed by biomarker data was 1·7 mg/mg, due to both high Na intake and low K intake. Only 5·2 % of the NYC population had an optimal Na:K, suggesting there are very few who meet dietary recommendations for Na and K intakes. These findings are consistent with national data from the National Health and Nutrition Examination Survey 2003–2008 using 24 h dietary recall[4].

In our analysis, young adults (age 18–25 years) had the highest Na:K. Further, a less-than-optimal Na:K was associated with obesity and physical inactivity, both independent risk factors for CVD. The association with younger age raises concerns about poor dietary behaviours in early adulthood, which could increase the risk of premature CVD[13].

Adhering to the daily recommended Na limit for most adults (2300 mg) and the daily recommended K intake (4700 mg) would result in an Na:K of <0·5 mg/mg. Even fewer NYC adults would meet this lower ratio. The main dietary recommendation to increase K is to increase fruit and vegetable consumption; this was corroborated in our study, since a lower Na:K was associated with five or more daily servings of fruits and vegetables. A lower Na:K was also associated with lower fast-food and sugary drink consumption, suggesting that environmental changes to lower consumption of these foods, while increasing access to fruits and vegetables, could help shift the population Na:K.

Table 1 Mean sodium:potassium, sodium and potassium intakes; 2010 Community Health Survey Heart Follow-Up Study (HFUS), New York City, USA

	Mean Na:K		Mean Na (mg/d)		Mean K (mg/d)	
	Weighted mean	95 % CI	Weighted mean	95 % CI	Weighted mean	95 % CI
Overall	1·7	1·6, 1·8	3239	3119, 3359	2175	2093, 2257
Age group						
18–24 years	2·2*	2·0, 2·4	3445	3067, 3823	1716*	1532, 1899
25–44 years (Ref.)†	1·7	1·6, 1·8	3248	3038, 3457	2190	2036, 2343
45–64 years	1·7	1·6, 1·8	3467	3286, 3649	2356	2235, 2477
≥65 years	1·3*	1·2, 1·4	2630*	2452, 2809	2201	2071, 2330
P trend	< 0·01		< 0·01		< 0·01	
Sex						
Male	1·7	1·6, 1·8	3583*	3392, 3775	2387*	2241, 2533
Female (Ref.)	1·7	1·6, 1·8	2944	2799, 3088	1993	1907, 2078
Race						
Non-Hispanic White (Ref.)	1·4	1·3, 1·5	3066	2892, 3240	2524	2369, 2679
Non-Hispanic Black	2·1*	2·0, 2·3	3477*	3204, 3751	1847*	1690, 2004
Hispanic	1·8*	1·7, 1·9	3395*	3153, 3637	2021*	1897, 2144
Non-Hispanic Asian	1·6	1·4, 1·8	3068	2626, 3510	2034*	1869, 2198
Other	1·7§	1·3, 2·1	2992§	2649, 3335	1975*,§	1619, 2331
Poverty income ratio						
< 200 % FPL	1·8*	1·7, 2·0	3306	3123, 3488	1987*	1890, 2084
200–399 % FPL	1·7*	1·5, 1·9	3350	3076, 3624	2168*	2015, 2322
≥ 400 % FPL (Ref.)	1·4	1·3, 1·5	3200	2983, 3416	2553	2358, 2749
P trend	< 0·01		0·20		< 0·01	
Education						
Less than high school	1·9*	1·8, 2·1	3376	3084, 3669	1938*	1778, 2097
Grade 12 or GED	1·9*	1·7, 2·0	3365	3111, 3619	1988*	1862, 2113
Some college	1·7*	1·6, 1·9	3166	2936, 3396	2060*	1925, 2196
College graduate (Ref.)	1·4	1·3, 1·5	3096	2901, 3290	2576	2394, 2758
P trend	< 0·01		0·25		< 0·01	
Country of birth						
US-born (Ref.)	1·8	1·7, 1·9	3299	3135, 3462	2132	2016, 2249
Foreign-born‡	1·6*	1·5, 1·7	3176	2999, 3353	2227	2110, 2343
BMI category						
Underweight, < 18·5 kg/m^2	1·9§	1·1, 2·7	3130§	2103, 4157	1852*,§	1514, 2190
Normal, 18·5– < 25·0 kg/m^2 (Ref.)	1·5	1·4, 1·7	3040	2835, 3245	2228	2100, 2355
Overweight, 25·0– < 30·0 kg/m^2	1·6	1·5, 1·7	3114	2925, 3303	2151	1997, 2304
Obese, ≥ 30·0 kg/m^2	1·9*	1·8, 2·0	3609*	3381, 3837	2179	2021, 2337
P trend	< 0·01		< 0·01		0·24	
Smoking						
Never (Ref.)	1·7	1·6, 1·8	3149	2999, 3299	2124	2015, 2234
Current	1·9	1·7, 2·0	3496*	3195, 3796	2143	1934, 2351
Former	1·6	1·4, 1·7	3287	3025, 3549	2334*	2182, 2486
Performed physical activity in last 30 d						
Yes	1·6	1·6, 1·7	3152	3014, 3290	2197	2101, 2293
No (Ref.)	1·9*	1·7, 2·0	3491*	3256, 3727	2110	1950, 2271
Fruit and vegetable intake						
None (Ref.)	1·9	1·8, 2·1	3296	2969, 3624	1842	1655, 2029
1 to 4 servings/d	1·7*	1·6, 1·8	3270	3127, 3414	2166*	2069, 2263
5 + servings/d	1·4*	1·2, 1·5	3050	2756, 3345	2531*	2300, 2762
P trend	< 0·01		0·39		< 0·01	
Times per week eat fast food						
None (Ref.)	1·5	1·4, 1·6	3126	2969, 3283	2385	2258, 2512
< 1	1·8*	1·7, 2·0	3293	3045, 3542	1965*	1837, 2093
1 to < 2	1·9*	1·7, 2·0	3513	3125, 3902	2031*	1819, 2243
2 to < 3	2·0*	1·7, 2·2	3604	3036, 4172	2075	1766, 2383
3 to < 6	2·0*	1·8, 2·3	3200	2745, 3655	1650*	1371, 1929
P trend	< 0·01		0·23		< 0·01	
Two or more sodas daily						
Yes	2·2*	2·0, 2·5	3915*	3416, 4413	1911	1630, 2192
No (Ref.)	1·6	1·6, 1·7	3166	3048, 3284	2202	2116, 2288

Ref., reference category; FPL, federal poverty level; GED, General Educational Development.
P value for trend is calculated for ordinal, categorical variables using the Wald χ^2 test.
*Statistical significance at $P < 0·05$, *P* value compares mean in subgroup to reference.
†Reference group is 25–44-year-olds due to smaller sample size in the 18–24-year-old group.
‡Because diet and culture heavily influence Na and K intakes, those reporting being born in Puerto Rico or other US Territories were considered 'foreign-born'.
§Estimate's relative standard error is greater than 30 % or the sample size is less than fifty, making the estimate potentially unreliable.

Although 24 h urinary Na excretion is the gold standard measure of Na and K intake, it reflects ~ 97 % of Na consumed but only ~80–85 % of K intake[14]. Thus, the urinary Na:K used in the current analysis may overestimate the true ratio. While the current study used the gold standard methodology of estimating Na intake through the measurement of rigorously collected 24 h urine, limitations to this methodology exist. The potential for incomplete collection of urine by the participant is a primary limitation of this methodology. From study design to implementation, to laboratory and data analysis, the HFUS investigators took this into consideration and has been previously described[15]. Another limitation is that one 24 h collection may not be representative of an individual's typical intake given the high intra-person variability of Na excretion, although this is less problematic when assessing estimates at the population level. As an additional note, the units of Na:K differ depending on the measurement method (mg *v.* mmol). This affects the magnitude of the effect of a one-unit change, and should be considered when interpreting results across studies. Lastly, the results presented are only representative of the non-institutionalized adult population. While participation of different subgroups in the HFUS was similar to the overall CHS sample, there may be a slight over-representation of younger, lower-income and/or Hispanic adults. Expansion of the random digit-dial methodology to include cellular telephone users broadened the reach of the survey to those who do not have landline access, and improved representativeness. Similar methods have since been implemented at the national level[16].

Improvements in meeting both Na and K daily intake recommendations could decrease risk of CVD, the leading cause of death. Na:K is a potential surveillance tool that can assess dietary changes over time in a single marker and can identify populations at high risk for nutrition-related chronic disease.

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