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ORIGINAL CONTRIBUTION

Sodium and potassium intakes in the Kazakhstan population estimated using 24-h urinary excretion: evidence for national action

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Abstract

Purpose There is strong scientific evidence for reducing sodium and increasing potassium intake to the recommended levels to lower blood pressure and cardiovascular risk, but consumption levels in Kazakhstan are unknown. This study sought to estimate mean sodium and potassium intake using 24-h urine samples and describe dietary knowledge and behavior among adults in Kazakhstan.

Methods In two cross-sectional surveys, the same multi-stage cluster sampling method was used to randomly select participants aged 25–64 years from Almaty City in 2015 and Kyzylorda in 2016. Complete 24-h urine samples were available for 478 participants; 294 in Almaty City and 184 in Kyzylorda (response rates 86% and 54%, respectively) and were weighted for the age and sex distribution of the two regions.

Results Weighted mean 24-h urinary sodium excretion was 6782 mg/day (17.2 g salt) (95% CI 6507–7058) in both regions combined, and not significantly different between the regions ($P=0.660$). 99% of adults in the two regions combined consumed above the World Health Organization's (WHO) recommended sodium maximum of 2000 mg/day; however, only 15% of adults perceived that they consumed excess sodium. Weighted mean 24-h urinary potassium excretion was 2271 mg/day (95% CI 2151–2391) for the regions combined.

Conclusion Mean sodium consumption in Kazakhstan was more than triple the WHO's recommended maximum, and mean potassium consumption was below the recommended minimum. National efforts to lower sodium intake and increase potassium intake are needed and would likely prevent ample premature deaths and disease burden.

Keywords Sodium · Salt · Potassium · Hypertension · Food policy · Nutrition

Introduction

Cardiovascular diseases (CVDs) are the leading cause of death in Kazakhstan responsible for half of all deaths, and hypertension is a key risk factor that affects about a quarter of adults aged ≥ 18 years [1, 2]. There is methodologically rigorous evidence showing that excess sodium intake (usually consumed in the form of salt) and insufficient potassium intake are major contributors to elevated blood pressure and increased CVD risk [3–7]. Due to the compelling evidence base, leading health and medical organizations, including the World Health Organization (WHO) recommend adults and children should consume less sodium (< 2000 mg/day) and more potassium (> 3510 mg/day) [8–10]. Furthermore, all WHO Member States have committed to achieving a global target of a 30% reduction in mean population sodium intake

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by 2025 to combat non-communicable diseases (NCDs) [11].

In Kazakhstan, there has been no accurate data on sodium or potassium consumption in the population; however, several international studies such as INTERSALT [12], INTERMAP [13] and Powles et al. [14], suggest that countries in the Central Asian region have some of the highest sodium intakes worldwide, and have lower potassium intake than other regions [12, 13]. Furthermore, studies of different minority ethnic groups living in China found that the Kazakh people have one of the highest prevalence rates of hypertension (50% in men and 41% in women), which was linked to their dietary habits characterised by high intakes of sodium and fat, and low consumption of fresh fruit and vegetables [15–17]. While it is suspected that consumption of sodium is high and potassium is low in Kazakhstan, the absence of accurate, local data hinders concerted action. Therefore, the objective of this study was to estimate sodium intake among adults in two regions of Kazakhstan from 24-h urinary excretion, the gold standard method. Secondary objectives were to describe 24-h urinary potassium excretion, the sodium-to-potassium molar ratio and dietary knowledge and behaviors.

Methods

The two cross-sectional surveys were undertaken in June to August 2015 in Almaty City and in July to August in 2016 in Kyzylorda, by the Kazakh Academy of Nutrition (KAN) in collaboration with Ministry of Education and Science of the Republic of Kazakhstan. The same survey methodology was used for the two surveys. Almaty City was chosen as it is the largest city, where almost 10% of the population lives and Kyzylorda was chosen, because it was different, comprising of rural and urban regions. Each respondent was briefed on the project and provided written informed consent. The project received ethical approval by the KAN's Ethics Committee (Project #2524/ГФ4).

Study population

In both surveys, multi-stage cluster sampling method was used to randomly select participants for recruitment. In Almaty City, 20 clusters were randomly selected from all eight city districts. In Kyzylorda, 20 clusters were also randomly selected; 10 urban and 10 rural areas. In both regions, clusters were based on existing regions of medical care delivery (for example urban polyclinics, medical outpatient and rural outpatient clinics). A list of the households within the clusters was generated and systematic random sampling was used to select 17 households from each cluster. One participant was then selected per household, meaning a total of 340 participants were selected for each survey. Participants were notified of selection through health professionals from the urban and rural polyclinics and outpatient clinics. The interviewer then administered the survey at the participant's house after obtaining written informed consent. Participants aged 25–64 years were included in the survey, and excluded if they reported taking diuretics during the last week, were pregnant or menstruating at the time of the interview.

Data collection and measurements

The surveys were conducted by trained staff of the KAN and trained district nurses. Consenting participants completed a questionnaire about their demographics, clinical characteristics, history of illnesses, the frequency of consumption of salty foods and knowledge, attitudes and behavior (KAB) in relation to salt and diet, which was designed based on the WHO STEPS NCD risk factors questionnaire [18]. In addition, anthropometric (height and weight) and blood pressure measurements were undertaken following the procedures outlined by the WHO STEPS survey [18]. Blood pressure was measured twice using an Omron digital automatic blood pressure monitor [18]. If the two readings differed by more than 5 mmHg, blood pressure was measured again, and the final recorded value was the average of the last two measurements.

Sodium and potassium intake was assessed using the preferred method of 24-h urine collection [8, 19, 20]. Participants were provided with detailed instructions and equipment (3 l plastic bottles and a measuring jug) to collect 24-h urine samples based on the WHO's standard protocol [18, 21]. Briefly, participants were advised to start collection the next day, and in the morning upon waking, participants were asked to discard the first urine void, then collect all subsequent urine voids through the day and night, up to and including the first urine void of the following day. After the completion of the 24-h urine collection, interviewers asked participants about any spilled or missed urine voids. If there were missed collections, participants were asked to re-collect 24-h urine on a convenient day. 24-h urine samples were measured and analysed by the laboratory "Healthy City" using the electrolyte analyser AVL 9180 to determine sodium, potassium and creatinine concentration. Suspected inaccurate or incomplete 24-h urine samples were excluded using the following criteria; 24-h urine volume of < 500 ml, 24-h urinary creatinine excretion of < 4 mmol and > 25 mmol for females and < 6 mmol and > 30 mmol for males [22].

Statistical analysis

All analyses were weighted to reflect the age (25–44 and 45–64 years) and sex distribution of the population in Almaty City and Kyzylorda based on the most recent census. Weighted means (95% confidence intervals- CI) of 24-h urinary sodium, potassium, creatinine excretions and their molar ratios were estimated using survey adjusted analyses [23]. The weighted proportions of the population with 24-h urinary excretion above the WHO-recommended guideline of 2000 mg of sodium/day was estimated [8, 9]. Differences in urinary sodium and potassium excretion between demographic and clinical subgroups were assessed using regression, as previous studies indicate variations by such subgroups [12, 14]. Demographic characteristics for exploratory analyses included age, sex, nationality, rurality, education and employment. Clinical characteristics included weight status based on body mass index (BMI, kg/m^2), measured blood pressure and history of hypertension. Dietary KAB were reported for the entire study population that met the participant inclusion and exclusion criteria (including those with inaccurate 24 h urine samples) and differences in between men and women were assessed using logistic regression.

Three sensitivity analyses were conducted to examine the robustness of the mean estimates of 24-h urinary excretion including no exclusions of 24 h urine collections, exclusions of potentially inaccurate urine collections based on another commonly-used creatinine criteria [22], and exclusion of individuals that self-reported having a liver or kidney condition or disease (which reflects the opinion of participants rather than a medical diagnosis by a health professional).

Statistical analyses were conducted using STATA IC version 15 for Windows (StataCorp LP, College Station, Texas, USA). Results are reported as mean and 95% CI as appropriate. Statistical significance was accepted at $P < 0.05$.

Results

Population demographic and health characteristics

In total, 680 people were randomly selected to participate in the survey, 340 each from Almaty City and Kyzylorda. All invited participants consented to participation; however, 18 participants from Almaty City and 35 participants from Kyzylorda were excluded, because they did not meet the age criteria, were taking diuretics during the last week or were pregnant or menstruating at the time of the interview. A further 28 participants from Almaty City and 121 participants from Kyzylorda were excluded based on the established criteria for suspected inaccurate 24-h urine collection, leaving a total of 478 participants; 294 from Almaty City and 184 from Kyzylorda (Fig. 1). The overall response rate for Almaty City and Kyzylorda was 86% and 54%, respectively, for sodium and potassium excretion estimates. The demographic and clinical characteristics of included participants before and after weighting by age–sex distribution are presented in Table 1. In comparison to the distribution of characteristics among included participants who had accurate 24-h urine collections, those excluded for suspected inaccurate 24-h urine collection were proportionately higher among men ($P < 0.001$) and unemployed, student or other

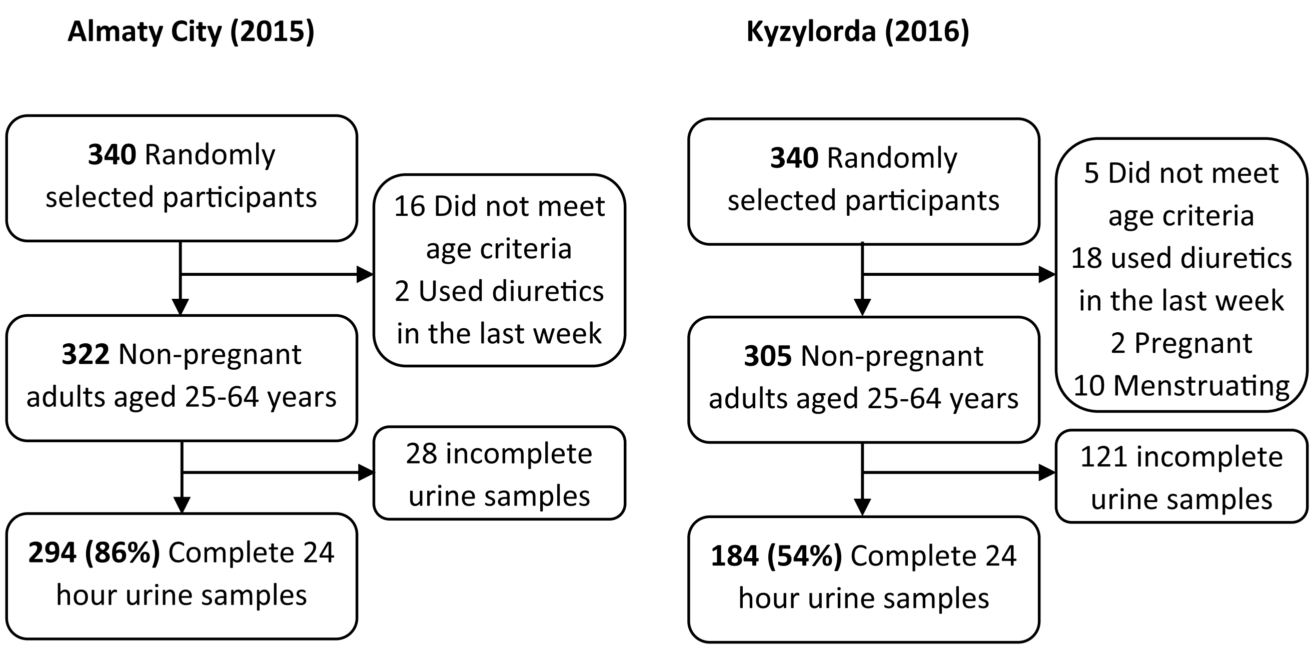

Fig. 1 Flow chart of participant recruitment and inclusion and exclusion

Table 1 Unweighted and weighted demographic and clinical characteristics of study population

Survey characteristics	2015 Almaty city ($n=294$)		2016 Kyzylorda ($n=184$)	
	Unweighted	Weighted	Unweighted	Weighted
Age, years (mean, SD)	43.7 (11.5)	41.4 (11.2)	42.5 (10.7)	40.2 (10.5)
Sex (%)				
Female	54.1	54.9	47.3	50.8
Nationality (%)				
Kazakh	69.4	70.1	100.0	100.0
Russian	22.5	21.1	0.0	0.0
Others	8.2	8.8	0.0	0.0
Highest education (%)				
Primary	0.3	0.3	1.6	1.4
Secondary	45.2	42.4	66.9	65.5
Tertiary	54.4	57.3	31.5	33.1
Employment (%)				
Employed	52.7	53.8	67.4	69.3
Unemployed, students & others	47.3	46.3	32.6	30.8
Location (%)				
Rural	–	–	53.80	53.78
BMI, kg/m^2 (mean, SD)	26.1 (4.9)	25.7 (4.9)	25.8 (4.4)	25.5 (4.4)
SBP, mmHg (mean, SD)	121.3 (15.6)	120.1 (15.2)	121.7 (17.0)	119.9 (16.5)
DBP, mmHg (mean, SD)	75.9 (10.5)	75.2 (10.5)	79.2 (12.0)	78.0 (11.8)
Measured hypertension (SBP ≥ 140 or DBP ≥ 90) (%)	14.3	12.5	20.7	17.5
Self-reported hypertension (%)	10.9	8.5	6.5	5.9
Self-reported kidney condition or disease (%)	18.0	17.9	30.4	31.3
Self-reported liver condition or disease (%)	15.7	15.6	18.5	18.0

BMI body mass index (kg/m^2), *SBP* systolic blood pressure, *DBP* diastolic blood pressure

($P=0.015$) in Almaty City, and urban residents ($P=0.046$), those with measured hypertension ($P=0.049$) and a history of hypertension ($P=0.017$) in Kyzylorda (Supplementary Table 1).

24-h urinary sodium excretion

Overall weighted mean 24-h urinary sodium excretion was 6782 mg/day (95% CI 6507–7058) (equivalent to 17.24 g salt) in both regions combined, 6731 mg/day (95% CI 6412–7046) in Almaty City and 6869 mg/day (95% CI 6322–7420) in Kyzylorda ($P=0.660$) (Table 2). All adults in Almaty City and 97% in Kyzylorda had 24-h urinary sodium excretion above the recommended level of 2000 mg/d. In Almaty City, mean sodium excretion was significantly higher among men compared with women (7294 vs 6267 mg/d, $P=0.002$) and among those with secondary school education or below compared to those with tertiary education (7325 vs 6287 mg/d, $P=0.002$) (Table 3). Whereas in Kyzylorda, mean sodium excretion was higher among urban compared with rural residents (8383 vs 5571 mg/d, $P<0.001$) and among those that were unemployed, students and other compared to those employed (8029 vs 6357 mg/d, $P=0.006$) (Table 3). 24-h urinary sodium excretion did not

Table 2 Weighted mean (95% CI) 24-h urinary sodium, potassium excretion and sodium-to-potassium ratio in Almaty City and Kyzylorda, and differences between regions

	Total ($n=478$)	Almaty city ($n=294$)	Kyzylorda ($n=184$)	*P* value
Sodium excretion (mg/day)	6782 (6507–7058)	6731 (6412–7046)	6869 (6322–7420)	0.660
Salt (grams/day)[a]	17.24 (16.54–17.94)	17.11 (16.30–17.91)	17.46 (16.07–18.86)	
Potassium excretion (mg/day)	2271 (2151–2391)	2091 (1984–2198)	2559 (2294–2823)	0.001
Sodium-to-potassium ratio (mmol/mmol)	6.34 (5.98–6.70)	6.06 (5.75–6.37)	6.78 (5.97–7.59)	0.107

[a]Salt in grams was calculated by dividing sodium excretion in mg by 393.4

Table 3 Differences in weighted 24-h urinary sodium and potassium excretion among different demographic and clinical subgroups

Demographic and clinical subgroups	Mean sodium intake, mg/day (95% CI)				Mean potassium intake, mg/day (95% CI)			
	Almaty city ($n=294$)	*P* value	Kyzylorda ($n=184$)	*P* value	Almaty city ($n=294$)	*P* value	Kyzylorda ($n=184$)	*P* value
Sex								
Women	6267 (5901–6633)	**0.002**	6491 (5712–7266)	0.163	1966 (1850–2083)	**0.014**	2736 (2305–3167)	0.178
Men	7294 (6770–7813)		7266 (6507–8021)		2243 (2056–2429)		2376 (2074–2677)	
Age group								
25–44	6593 (6161–7030)	0.265	7183 (6420–7951)	0.096	2064 (1915–2214)	0.509	2503 (2163–2844)	0.579
45–64	6944 (6507–7380)		6314 (5637–6995)		2134 (1992–2276)		2656 (2234–3078)	
Nationality								
Kazak	6845 (6452–7242)	0.233	6869 (6322–7420)	N/A	2118 (1985–2251)	0.418	2559 (2293–2825)	N/A
Russian and other	6452 (5936–6967)				2028 (1853–2202)			
Rurality								
Urban			8383 (7471–9296)	**<0.001**			3190 (2818–3562)	**< 0.001**
Rural			5571 (5055–6086)				2016 (1679–2353)	
Education completed								
Secondary or below[a]	7325 (6814–7837)	**0.002**	6684 (6078–7256)	0.381	2158 (1984–2332)	0.297	2581 (2243–2920)	0.804
Tertiary	6287 (5897–6676)		7250 (6121–8379)		2041 (1907–2175)		2513 (2093–2933)	
Employment								
Employed	6711 (6251–7180)	0.919	6357 (5724–6987)	**0.006**	2113 (1959–2268)	0.653	2602 (2269–2936)	0.608
Unemployed and student	6747 (6326–7168)		8029 (7014–9048)		2065 (1918–2211)		2461 (2033–2888)	
Body mass index								
Underweight/normal[a]	6578 (6125–7026)	0.344	6759 (5936–7577)	0.702	2053 (1898–2207)	0.481	2614 (2201–3027)	0.701
Overweight/obese[b]	6881 (6436–7325)		6971 (6231–7711)		2129 (1982–2277)		2510 (2167–2851)	
Blood pressure								
SBP < 140 and DBP < 90	6680 (6342–7018)	0.414	6940 (6310–7569)	0.530	2110 (1993–2227)	0.266	2635 (2336–2934)	0.172
SBP ≥ 140 or DBP ≥ 90	7069 (6200–7939)		6546 (5492–7604)		1958 (1717–2199)		2199 (1647–2751)	
History of hypertension								
Yes	7231 (6035–8427)	0.385	6578 (4945–8214)	0.725	2203 (1936–2471)	0.406	2440 (1683–3196)	0.758
No	6684 (6357–7010)		6888 (6314–7463)		2081 (1966–2195)		2566 (2288–2844)	

Bold *P*-values indicate statistical significance at $P < 0.05$

[a]Underweight/normal body mass index < 25 kg/m^2

[b]Overweight/obese body mass index ≥ 25 kg/m^2

SBP systolic blood pressure, *DBP* diastolic blood pressure

differ significantly across different age, nationality, BMI, measured blood pressure and history of hypertension subgroups in Almaty City and Kyzylorda (Table 3).

24-h urinary potassium excretion and the sodium-to-potassium molar ratio

Overall weighted mean 24-h urinary potassium excretion was 2271 mg/day (95% CI 2151–2391) in regions combined, with potassium excretion being lower in Almaty City (2091 mg/d, 95% CI 1984–2198) than in Kyzylorda (2559 mg/d, 95% CI 2294–2823) ($P=0.001$) (Table 2). 24-h urinary potassium excretion was significantly higher among men compared to women in Almaty City (2243 vs 1966 mg/d, $P=0.014$) and in urban compared to rural areas in Kyzylorda (3190 vs 2016 mg/d, $P<0.001$) (Table 3). There were no other differences in 24-h urinary potassium excretion among different subgroups in each region (Table 3).

The overall mean sodium-to-potassium molar ratio (Na:K) was 6.34 (95% CI 5.98–6.70) in the regions combined, 6.06 (95% CI 5.75–6.37) in Almaty City and 6.78 (95% CI 5.97–7.59) in Kyzylorda ($P=0.107$) (Table 2). In Kyzylorda, the Na:K ratio was higher in men compared to women in Kyzylorda ($P=0.009$), and among unemployed, students and other compared to employed people ($P=0.036$).

Sensitivity analyses

Estimates of weighted mean 24-h urinary sodium excretion in the two regions combined differed by +1.5% when there were no exclusions of 24-h urine samples, to +13.5% when a more stringent criteria for excluding inaccurate 24-h urine collections based on observed-to-expected 24-h urinary creatinine excretion of < 70% was used [24] (Supplementary Table 2). Estimates of weighted mean 24-h urinary potassium excretion in the two regions combined differed by +5.5% when those that self-reported having a liver or kidney condition or disease were excluded, to +30.6% when 24-h urine collections were excluded based on observed-to-expected 24-h urinary creatinine excretion of < 70% [24].

Diet and salt-related knowledge, attitudes and behaviors

Weighted estimates of diet and salt-related KAB are reported for the entire study sample (regardless of whether they had complete 24 h urine samples) in two regions separately in Fig. 2. Although 76% of adults in Almaty City and Kyzylorda were aware that excess salt intake caused adverse health effects, only 37% and 51%, respectively, identified it caused high blood pressure. Correspondingly, 67% and 77% of adults in Almaty City and Kyzylorda, respectively, thought that it was necessary to limit salt consumption; however, only 13% and 17%, respectively, thought that their own intake was too high. In both regions, the most common salty-food behaviors were use of condiments or seasonings more than once a week in over one-third of people; consumption of smoked, salted or dried foods; followed by out-of-home dining (Fig. 3). A low proportion of adults reported 'always or often' adding salt at the table or during eating; however, it was significantly higher in Almaty City (11%) compared to Kyzylorda (5%) ($P=0.006$). In both regions, women had significantly higher knowledge compared to men about the adverse and hypertensive effects of excess salt intake, and

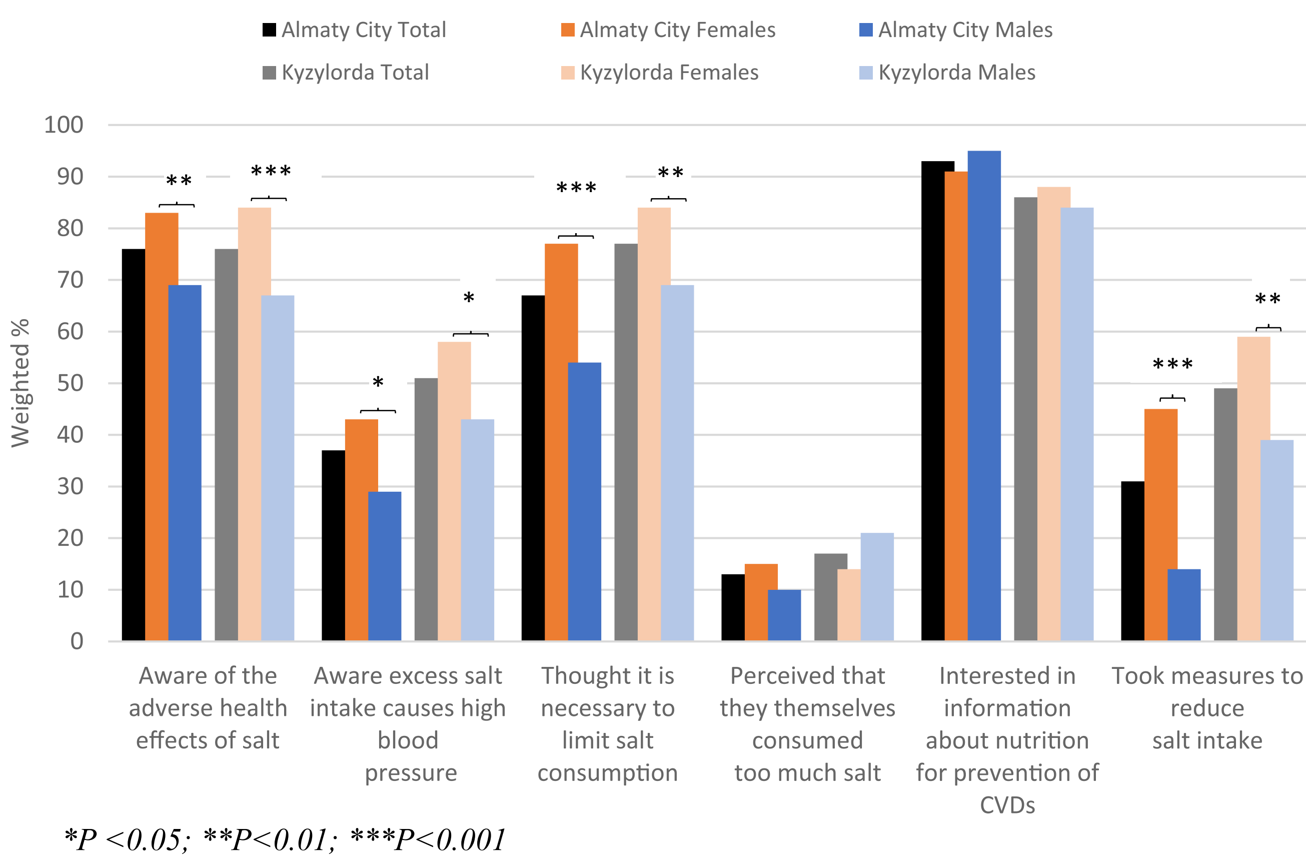

Fig. 2 Salt-related knowledge and attitudes among adults in Almaty City ($n=322$) and Kyzylorda (n = 305), and differences between men and women

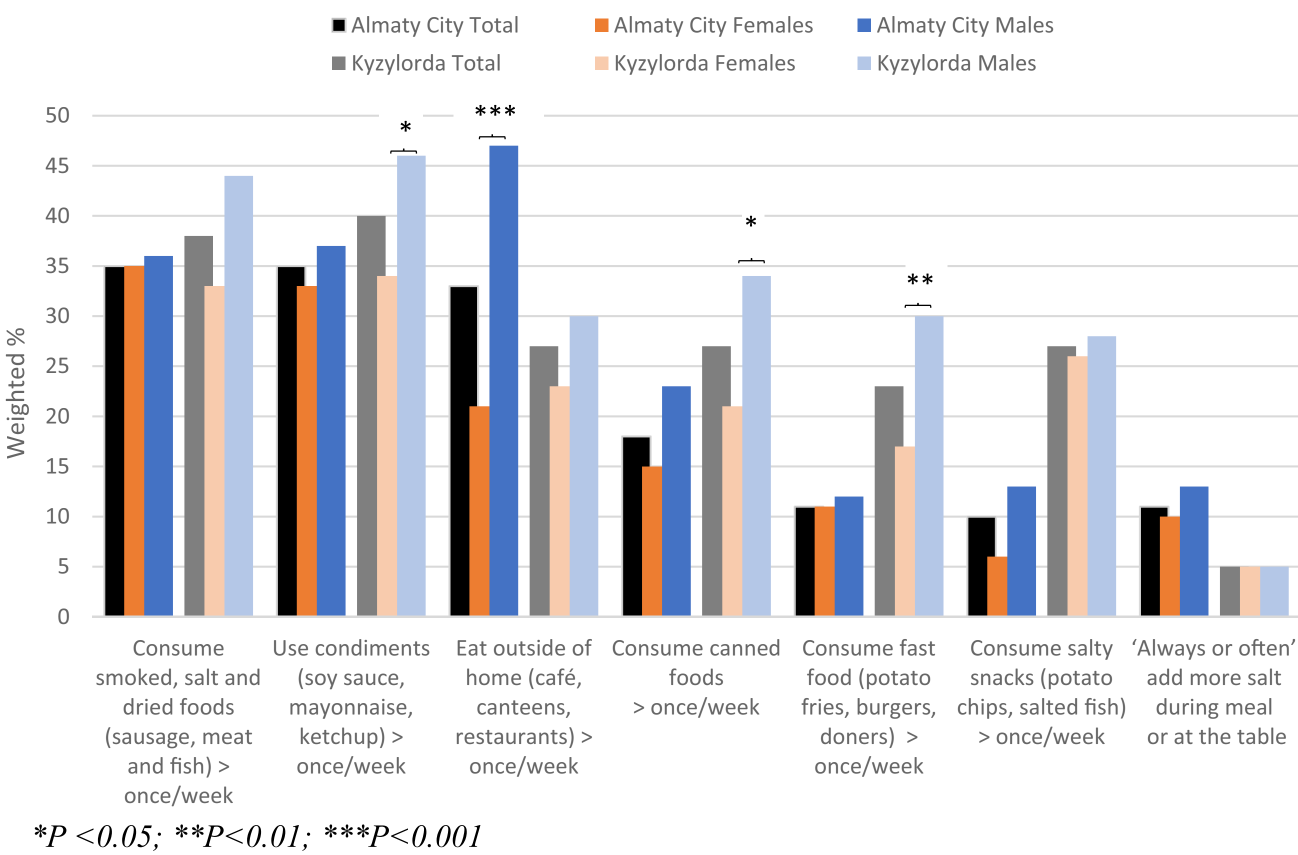

Fig. 3 Salt and dietary-related behaviors among adults in Almaty City ($n=322$) and Kyzylorda (n = 305), and differences between men and women

the necessity to limit salt consumption and took measures to reduce salt intake ($P<0.05$ for all) (Fig. 2).

Discussion

This first robust measurement of sodium and potassium intake in adults from two regions in Kazakhstan (Almaty City and Kyzylorda), based on the preferred method of 24-h urine collection suggests mean sodium consumption is more than triple (6782 mg/day) the WHO-recommended maximum, and potassium consumption is below the WHO-recommended minimum level required for lowering blood pressure and cardiovascular disease risk. Sodium intakes were high in all population subgroups and nearly all adults in Kazakhstan consumed above the WHO maximum of 2000 mg/day; however, only 15% of adults recognized their own intake was above the recommended level. The low rates of awareness about their excess sodium consumption levels may be due to their long history of a high salt intake as traditional diets of nomadic people were often foods preserved with salt including salted air-dried meats, salty fermented yogurt (kurt) and salted milk tea [14, 15, 26]. These dietary practices have continued as the consumption of smoked, salted and dried foods was a common food intake pattern reported in both regions. This study shows unequivocally that the Kazakhstan population would benefit from a national strategy to lower sodium consumption and increase potassium consumption, particularly given the high burden of hypertension and cardiovascular diseases.

Our measurements of mean sodium excretion of 6782 mg/day (median of 6357 mg) among Kazakhstan adults in 2015–2016 were higher (10%) than the estimate of 5980 mg/day (15.2 g salt) (95% uncertainty interval 5070–7140 mg/d) based on Bayesian hierarchical modelling, which borrows data within and across countries, and uses covariate data to estimate sodium intake in countries with missing data [14]. While there are limitations in the Bayesian model estimations of sodium intake in countries worldwide, our study which measured sodium intake using the gold standard method, provides support to their sodium intake estimate in Kazakhstan which was suggested to be the highest in the world [14]. Our median estimates of sodium intake were similar to those of Kazakhs living in Xinjiang China (6491 mg per day), though it was estimated based on second morning spot urine samples which is a less accurate method of measuring sodium intake [20, 25]. While there are slight differences in estimates, likely due to differences in the assessment methods and intake levels in different population subgroups, they consistently demonstrate mean population sodium intake in Kazakhstan is at least three times higher than the WHO-recommended maximum, and likely the highest in the world [14]. The high salt intake is unsurprising, given some commonly-consumed traditional dishes such as lagman (pulled noodles with meat and vegetables) and plov (rice pilaf with meat, carrot and spices) contained more than the whole day's recommended limit in one serve [26]. The significantly higher sodium consumption among urban compared to rural residents in Kyzylorda may be explained by the substantially higher consumption of salty meat and meat products (189.4 vs 20.7 g/person/day), estimated based on household consumption surveys [27]. Like other populations worldwide, higher sodium intake among men compared to women may be explained by higher food intake [12, 14, 28]; however, in addition, a lower proportion of men in Kazakhstan were aware of the adverse effects of excess sodium consumption, thought it was necessary to limit sodium, and took measures to reduce sodium intake compared to women. The lack of an association between sodium intake and blood pressure is unsurprising and is a frequent finding of cross-sectional studies of this kind due to the lack of temporality and the large errors in the measurements of both parameters at an individual level [29–31].

Mean 24-h urinary potassium excretion was 2271 mg per day, less than the WHO-recommended minimum of 3510 mg per day to reduce blood pressure and CVD risk [9]. Even after accounting for non-urinary losses (roughly 30% mainly in faces) [32, 33], through a 1.3 conversion [6], estimates of potassium intake (2952 mg/d) were still below (84%) the WHO minimum recommended level [9]. While there are no previous estimates of potassium intake in Kazakhstan, the low levels are supported by surveys that suggest 92% of men and 89% of women consume less than the recommended 400 g/day of fruits and vegetables (main sources of potassium) [34]. The findings of significantly lower potassium excretion in Almaty City compared to Kyzylorda may be explained by differences in fruit consumption based on household consumption surveys (178.9 in Almaty City vs 197.6 g/day per person in Kyzylorda) [27]. Given there is increasing evidence suggesting that the sodium-to-potassium ratio is a stronger predictor of blood pressure than either sodium or potassium alone, [35] and increasing potassium intake has a greater blood pressure-lowering effect when sodium intake is high (> 4000 mg/d), [6] this suggests strategies to jointly lower sodium and increase potassium intake in Kazakhstan may be a more efficient approach to lowering hypertension [36].

Key strengths of this survey were the adequate sample sizes and that population sodium and potassium intake was assessed using the gold standard method of 24-h urinary excretion of sodium and potassium, following the WHO guidelines [21]. In addition, most of the salt-related KAB questions were based on the WHO STEPS survey which allows for global comparison [18]. Both surveys were conducted among randomly selected participants who all consented and weighting was undertaken to reflect the age and sex distribution of the population in Almaty City and Kyzylorda. This means that the summary estimates should be good reflections of the mean sodium and potassium intake in the two regions. This study also has limitations. While the gold standard method of measurement was used, exclusions were made based on an established criteria for identifying inaccurate 24-h urine collections, which lowered the response rate. The sensitivity analyses demonstrated when different methods were used for excluding inaccurate 24-h urine samples, sodium estimates did not substantially differ and the primary estimate was more conservative; however, potassium estimates were more variable. It cannot be excluded that some of the findings about the differences in sodium and potassium intake among subgroups (e.g., higher sodium and potassium intake in urban vs rural resident in Kyzylorda) may be due to selection bias.

These study findings provide clear evidence of two key modifiable risk factors that have huge potential for public health benefit in Kazakhstan; (1) sodium intake that is on average more than triple the recommended maximum, and (2) potassium intake that is below the recommended minimum [8, 9]. Given that Kazakhstan potentially has the highest sodium intake in the world and that there is a dose–response relationship between sodium reduction and blood pressure lowering [7], modelling studies suggest that a multi-faceted intervention to reduce population sodium intake by 10% would be the most efficacious in Kazakhstan out of all 183 countries assessed, and are highly cost-effective [37]. Furthermore, efforts to increase potassium intake alongside sodium reduction can provide added effects on blood pressure lowering, particularly when sodium intake is high [6]. Thereby, a multi-faceted national strategy targeting the population's low awareness of their adversely high sodium intakes and inadequate potassium intakes, salt preservation dietary habits and salty traditional dishes, and improved food environment for increased fruit and vegetable intakes, is needed. An effective national strategy that both lowers sodium intake and increases potassium intake in Kazakhstan should substantially contribute to reducing the burden of NCDs.

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Author contribution FO and ST designed and conducted the research; JJ and JB provided essential materials; KT and JAS analysed the data, KT and JW wrote the paper; KT had primary responsibility for final content. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflicts of interest JW is Director of the WHO Collaborating Centre on Population Salt Reduction. The co-authors Jo Jewell and Joao Breda were staff members of the WHO Regional Office for Europe at the time of the study. The authors are responsible for the views expressed in this publication and they do not necessarily represent the decisions or stated policy of WHO. All other authors declare that they have no other competing interests related to this review.

Ethics approval The project received ethical approval by the Kazakh Academy of Nutrition Ethics Committee (Project #2524/ГФ4).

Informed consent Each participant was briefed on the project and provided written informed consent.

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