

Salt intake of the Slovene population assessed by 24 h urinary sodium excretion

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Abstract

Objective: To investigate average sodium excretion in 24 h urine as a marker for salt intake in the Slovene population.

Design: Salt intake was determined by measuring sodium excretion in 24 h urine collected from a representative sample of geographically diverse Slovene adults.

Setting: Slovenia.

Subjects: A random sample of 600 adults aged 25–65 years was generated from census data. The effective sample yield was 143 people, 42·7% men and 57·3% women.

Results: Urinary sodium excretion was significantly higher in men (220·9 (SD 86·0) mmol Na/d) than in women (169·8 (SD 73·8) mmol Na/d); *t* test = 14·5, *P* < 0·001. Average salt intake was 11·3 (SD 4·9) g/d, higher in men than in women (13·0 (SD 5·1) *v.* 9·9 (SD 4·3) g/d, respectively). Average intakes of salt among regions were not significantly different. Salt intake increases slightly with increasing age, but there was no significant correlation between age and salt intake. Salt intake was increased with BMI (*r* = 0·384, *P* < 0·001).

Conclusions: Salt intake in Slovene adults, especially in men, exceeds the WHO recommended population nutrient intake goal of 5 g by more than twofold. A national programme for reducing salt intake in Slovenia needs to be implemented through systematic efforts including public education and involving the health-care sector and the food industry.

Keywords
Salt intake
24 h urine collection
Body mass index
Regions

In 2005, thirty-five million people died from chronic diseases worldwide, which represents 60% of the total number of deaths (fifty-eight million) in that year. Of all deaths from chronic diseases in 2005, 30% were due to CVD⁽¹⁾. In Slovenia CVD is the leading cause of death (40% of all deaths)⁽²⁾. There is strong conclusive evidence of the adverse effects of excessive dietary salt intake on blood pressure, and high blood pressure is a risk factor for CVD^(3–7). Observational studies also show associations between salt intake and BMI⁽⁸⁾.

Sodium plays an important and diverse role in mammalian physiology, including regulation of the extracellular fluid volume, water balance and generation of the membrane potential of cells. While sodium is an essential nutrient in man, the estimated value for minimum daily sodium intake for adults is 550 mg (24 mmol) in accordance with the reference values for nutrient intake⁽⁹⁾. For many populations, salt intake averages 10 g/d (172 mmol Na/d) and large numbers of people consume 12 g/d (207 mmol Na/d) or more. By the late 1980s, when INTERSALT also

studied three population samples in Japan, median 24 h sodium excretion was 169–214 mmol Na/d for men⁽¹⁰⁾.

The level of salt in our diets and its impact on health remains a public health problem in many regions of the world. For many years, concerns have been expressed that, at least in the Western world, intakes of salt (sodium) are well above those needed for nutritional purposes, and that these are having adverse effects on health⁽¹¹⁾.

In Slovenia, we adopted the joint WHO/FAO recommendations that state that the population nutrient intake goal for salt should be <5 g/d (or 2 g Na/d), while ensuring that the salt is iodised⁽¹²⁾.

There are several methods for evaluating salt intake, such as dietary recall or records from 24 to 96 h, FFQ and 24 h urine collection. Generally, 24 h urine collection is considered to be the most reliable method to evaluate salt intake^(13–18). Dietary survey methods tend to underestimate sodium intake, and 24 h urinary sodium excretion is considered the 'gold standard' method to estimate intake⁽¹⁹⁾. The 24 h urinary excretion method does not

account for electrolyte loss other than via the kidneys, and therefore will tend to slightly underestimate the true intake. For example, Holbrook *et al.*⁽²⁰⁾ reported that among twenty-eight adults, the average urinary excretion of sodium from seven consecutive 24 h urine collections was 86% of that estimated from chemical analysis of duplicate diets collected over the same 7 d period.

The objective of the present study was to evaluate sodium excretion in 24 h urine samples for a sample of the Slovene population as a marker for salt intake in Slovene adults. Despite its limitation, 24 h urinary creatinine was used as a standard to exclude urine collection judged to be incomplete⁽²¹⁾. We also investigated salt intake according to geographical differences, age and BMI.

Experimental methods

Participants

The present study included 143 participants between 25 and 65 years old: 42.7% men and 57.3% women. The basic random sample in the present study represented a list of 600 people with names and surnames, years of birth and home addresses. The participants were randomly sampled from census data and the list was prepared by the Statistical Office of the Republic of Slovenia in September 2007. The investigation took place in all regions of Slovenia, as determined according to the regional units of the Health Insurance Institute of Slovenia⁽²²⁾.

The participants received written invitations to take part in the survey, including an explanation of the purpose, the course of the survey and a request not to change their diet before or during the urine collection, as well as a consent form. Participants who signed and returned the consent forms received a letter of thanks and further instructions about the procedure that contained guidance for carrying out the 24 h urine collection⁽¹⁷⁾.

To maximise participation, the invitation included information on the prevalence of chronic diseases in Slovenia and worldwide, particularly information on high salt intake as a risk factor. In addition, we also stated that after the survey was completed every participant would receive nutritional recommendations according to their results.

Signed consent forms represented the basis for selection of the sample units. The urine samples were collected at fifty-nine regional health centres on three Mondays, the 19th and 26th of November and the 3rd of December 2007. These dates were chosen by the participants in the consent form. The study protocol was approved by the National Medical Ethics Committee (no. 43/8/07).

We received 158 signed consent forms. Only eleven urine samples were not delivered to the laboratory. By using the method of 24 h creatinine excretion measurements to exclude incomplete urine samples, four more urine samples were excluded from the survey. Therefore,

the effective sample for determination of sodium in 24 h urine decreased to 143 participants.

The number of participants from each region was proportional to the number of inhabitants of that region. The sample size was calculated from the known estimates of studies with similar methodologies from England, Scotland and Wales^(23–25). While these surveys have estimated a daily intake of 10 (SD 4) g of salt for men, we decided to take into account the range of sample accuracy within 15% to consider the differences in culture in dietary intakes between populations in Slovenia and the countries with the referential estimates used in the sample size in equation (1).

It was expected that this would yield samples sufficiently complete for analysis with a 95% CI for an estimate of standard deviation of 4 g of salt and within 15% of sample estimate accuracy in 170 individuals. The presumed difference of 15% represents the accounted error between true sample standard deviation and estimated sample standard deviation: 15% sample estimate accuracy for 170 individuals. The sample size was calculated by iteration of the following equation⁽²⁶⁾:

$$n' = \left(z_{\alpha/2} * \frac{s}{\Delta} \right)^2 \quad (1)$$

where $z_{\alpha/2}$ denotes the critical standards score, s the standard deviation and Δ the margin of error.

Taking into account the 24 h engagement of study participants on a definite date, which adds another restriction to the capacity to provide a whole planned sample, we used the effective sample size multiplied by approximately 3.5 in order to attain the complement of 600 people for the planned sample from randomly selected inhabitants.

Suitability of the effective sample in comparison to the planned random sample

We compared the structure adequacy of the effective sample (n 143) to that of the basic sample with regard to gender ($\chi^2 = 2.867$, $df = 1$, $P = 0.090$) and age ($t = -2.988$, $df = 600$, $P = 0.003$).

While the effective sample was not gender biased, the mean age of the effective sample was 47.6 (SD 11.6) years, and the mean age of the planned sample was 3 years less. We found that the difference in age distribution between the sample plan and sample realisation was statistically significant. By means of further analysis with age and sodium intake, we established that age does not interfere with sodium intake; therefore, the age distribution of the sample remained unweighted.

In relation to the geographical regions of participants' origins in this survey, we divided communities into three different regions of Slovenia: Alps, seacoast and central (continental). Differences between the included and excluded participants were not statistically significant ($\chi^2 = 0.314$; $df = 2$; $P = 0.855$).

Questionnaire

Each participant who returned the signed consent form received the questionnaire about gender, body weight and height, together with a special container and precise instructions for urine collection⁽¹⁷⁾. In addition, participants also had to include data on the time of the beginning and the end of urine collection. At the end of the urine collection, the participants had to return the questionnaires together with urine samples to the regional health centres.

24 h urine collection and measurements of urine volume, sodium and creatinine excretions

To determine daily sodium excretion we used 24 h urine collection. We also determined the urine volume and creatinine excretion. All procedures were conducted in accordance with the guidelines⁽¹⁷⁾. Detailed written instructions were given to the participants.

The 24 h urine collection was performed by collecting a person's urine in a special container over a 24 h period. The participants were asked to collect and record the time at the beginning (after the first morning urine collection) and the end (right after the morning urine collection the next day) of the 24 h urine collection period. On the day of the test, the participants were asked to void and empty the bladder in the morning (07.00 hours), discard the urine and note the time as the beginning of the collection. All urine voided in the next 24 h was collected in the container as part of the 24 h urine collection. After 24 h (07.00 hours on the next day), the bladder was emptied and the last void was deposited in the container as the final part of the collection. On the same morning, the urine samples were placed at the depot at fifty-nine regional health centres in Slovenia and transported to the University Institute of Clinical Chemistry and Biochemistry, Ljubljana, Slovenia. The total volume of urine collected was measured using a specially devised linear measuring scale. Urine aliquots were stored at -20°C before being shipped frozen to the University Institute of Clinical Chemistry and Biochemistry, Ljubljana, Slovenia, where all urine analyses were performed with strict internal and external quality control. Sodium excretions were measured by ion-selective electrode potentiometry with consideration of the total volume of the urine collected (litres) and the precise time of urine collection (hours and minutes)⁽²⁷⁾. According to standard practice in scientific literature, urinary sodium excretion is presented in mmol, whereas estimates of dietary salt intake are given in grams⁽¹⁹⁾.

For the conversion from sodium (Na) to sodium chloride (NaCl, i.e. salt), a factor 2.54 was used ($\text{NaCl (g)} = \text{Na (g)} \times 2.54$)⁽⁹⁾. Individual sodium excretion values were the products of concentrations in the urine and urinary volume corrected to 24 h and expressed as mmol/d.

Assuming that the rate of urinary creatinine excretion is constant, 24 h excretion of creatinine was used as a standard to exclude urine collection judged to be incomplete^(21,28,29). Creatinine was measured using the Jaffe method⁽³⁰⁾. The criterion for incompleteness of the urine sample introduced the individual body weight as a function of the amount of creatinine excretion by the formula:

$$\begin{aligned} &(\text{Concentration of creatinine in mmol/l} \\ &\times \text{Volume of urine in l}) / \text{Body weight in kg} \times 1000 \quad (2) \end{aligned}$$

Thus, a 24 h collection was not accepted if the creatinine excretion was $<120 \mu\text{mol/kg}$ body weight per d for men or $<124 \mu\text{mol/kg}$ body weight per d for women⁽³¹⁾. The coefficient of variation describes the variability in creatinine excretion between observed individuals.

Statistical analyses

Statistical analyses were performed with the Statistical Package for the Social Sciences statistical software package version 16.0 (SPSS Inc., Chicago, IL, USA).

Analyses included descriptive statistical as well as inferential statistical methods. Main group comparisons were performed using the χ^2 test. To obtain information about the relationships between variables, we used the Pearson correlation coefficient. We applied the t test to compare mean values of different groups after preliminary tests of homogeneity of variances were processed. All significance levels of statistical tests cited in the present study are two-sided.

Results

Estimates of reliability of biochemical variables

When estimating the parameters on the basis of a statistical sample, the relationship between sample size and the size of the entire population is not relevant. Reliability depends on standard error, which is the relationship between standard deviation and the square root of the sample size. Therefore, more homogeneous variables can also be established reliably enough with smaller samples. In the 95% CI, we estimated that the true mean of daily salt intake in the Slovene population for participants from 25 to 65 years old is between 10.5 and 12.1 g or, considering the secretion of sodium by skin and faeces, between 11.5 and 13.3 g. The true population's means of sodium and salt intake should be estimated by this sample within only 0.8 and 0.9 g sampling error, respectively⁽³²⁾.

Urine volume and creatinine excretion

Average urine volume was $1.93 (\text{SD } 0.61) \text{ l/d}$. Urine volume was significantly higher in men ($1.95 (\text{SD } 0.60) \text{ l/d}$) than in women ($1.91 (\text{SD } 0.63) \text{ l/d}$); F test = 0.212, $P = 0.646$, Table 1).

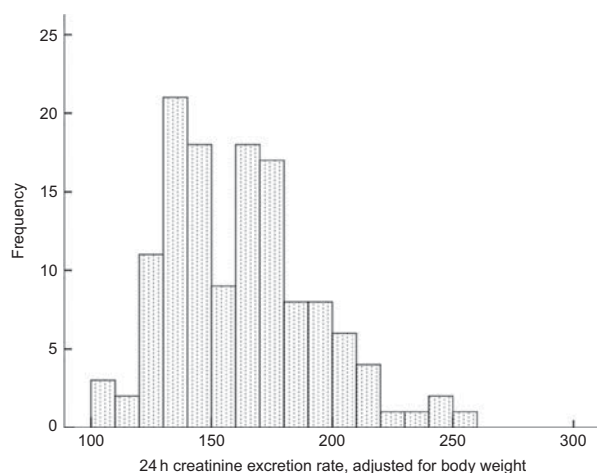
Urinary creatinine excretion was also significantly higher in men ($14.5 (\text{SD } 3.8) \text{ mmol/d}$) than in women

Table 1 Distribution of the results of 24 h urinary sodium excretion by age, height, weight, gender and BMI

	Men (<i>n</i> 61)		Women (<i>n</i> 82)		Total (<i>n</i> 143)		Test for difference between genders	
	Mean	SD	Mean	SD	Mean	SD	<i>F</i> test	<i>P</i> value
Age (years)	44.7	12.1	45.5	11.5	45.1	11.8	0.698	†
Height (cm)	177.4	7.2	164.4	5.9	169.9	9.1	–	–
Weight (kg)	84.6	14.1	69.7	11.9	76.0	14.8	–	–
BMI (kg/m ²)	26.9	4.3	25.8	4.3	26.1	4.3	–	–
Urinary volume (l/d)	1.95	0.60	1.91	0.63	1.93	0.61	0.212	†
Urinary creatinine (mmol/l)	8.3	3.5	6.0	2.6	7.0	3.2	20.128	<0.001
Urinary creatinine (mmol/d)	14.5	3.8	10.1	2.5	12.0	3.8	12.258	<0.001
Weight-adjusted creatinine (μmol/kg per d)	174.6	31.5	151.3	25.6	161.9	30.6	21.524	<0.001
Urinary Na excretion (mmol/d)	220.9	86.0	169.8	73.8	191.6	82.9	14.514	<0.001
Salt intake (g/d)*	13.0	5.1	9.9	4.3	11.3	4.9	14.573	<0.001

*1 mol of sodium (Na) corresponds to 23.0 g; for the conversion from sodium (Na) to sodium chloride (NaCl; i.e. salt), a factor 2.54 was used (NaCl (g) = Na (g) × 2.54)⁽⁹⁾.

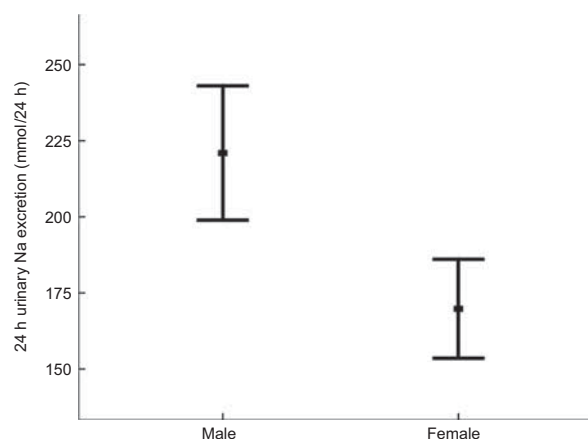
†Not significant.

**Fig. 1** The distribution of 24 h urinary creatinine excretion rate in units adjusted for body weight according to equation (2)

(10.1 (SD 2.5) mmol/d); *F* test = 12.258, *P* < 0.001, Table 1). Weight-adjusted levels of urinary sodium excretion were 161.9 (SD 30.6) μmol/kg, accounting for the difference of 174.6 (SD 31.5) μmol/kg for men and 151.3 (SD 25.6) μmol/kg for women (*F* test = 21.524, *P* < 0.001, Table 1). The coefficient of variation was 18.9% after the exclusion of incomplete urine samples. Figure 1 shows the distribution of values calculated by equation (2).

Sodium and salt intake in Slovene adults

Urinary sodium excretion was significantly higher in men (220.9 (SD 86.0) mmol/d) than in women (169.8 (SD 73.8) mmol/d); *t* test = 14.5, *P* < 0.001, Fig. 2). The quantities of sodium/salt measured in 24 h urine samples are significantly higher in men than in women in the amount of 30 mmol Na/d, i.e. 1.7 g salt/d (Table 1). Overall, with regard to the frequency distribution of salt data, 95% of the population had a daily intake higher than the recommended 5 g/d (100% of men, 91% of women).

**Fig. 2** The estimate of mean value of 24 h urinary sodium excretion for the Slovene population (*n* 143) by gender, with 95% CI represented by vertical bars

Sodium and salt intake by age and regions

In age comparison, statistically significant differences between the effective and the remnant sample occurred. In the effective sample, participants are 3 years older on average than the remnant sample (*t* = −2.988, *df* = 600, *P* < 0.003). Age distribution and its relation to salt intake in participants were estimated with the test. For this reason, the estimation of salt intake based on the effective sample can be slightly higher than the actual average of salt intake in the population of the same age range.

The average age in men and women was not significantly different, and there was no significant correlation between age and salt intake (Fig. 3). The average intake of salt in samples from the central (continental) region was 11.5 (SD 4.8) g/d, in the seacoast region 10.8 (SD 6.3) g/d and in the Alps region 10.4 (SD 4.0) g/d (Fig. 3). Average salt intakes among regions were not significantly different.

Sodium and salt intake by BMI

In our survey, all participants gave information about their weight and height. Average BMI was 26.9 (SD 4.3) kg/m² for

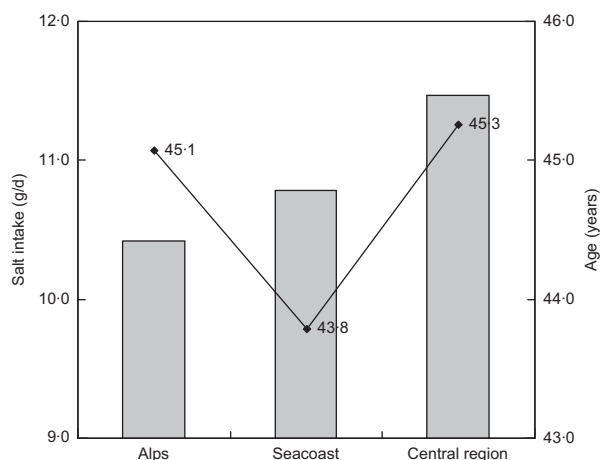


Fig. 3 Age (■) and average daily salt intake (—◆—) in Slovene adults in three Slovene regions

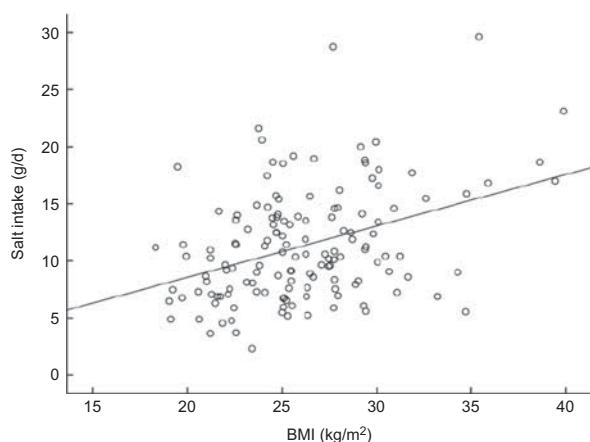


Fig. 4 Correlation between salt intake and BMI in Slovene adults

men and 25.8 ($SD\ 4.3$) kg/m^2 for women. Figure 4 shows a positive correlation between BMI and daily intake of salt ($r=0.384$, $P<0.001$). Accordingly, the coefficient of determination assessed by regression of salt *v.* BMI showed that 15% of the variability of BMI could be explained by the amount of daily salt intake.

Discussion

The present study shows the results of 24 h urinary sodium excretion to provide estimates of salt intake in the Slovene population. The study was carried out among a representative sample of adults from 25 to 65 years old. Average urinary sodium excretion was 191.6 ($SD\ 82.9$) $mmol\ Na/d$ (220.9 ($SD\ 86.0$) $mmol\ Na/d$ in men and 169.8 ($SD\ 73.8$) $mmol\ Na/d$ in women, Table 1). The INTERSALT study collected data on 24 h urinary sodium excretion for fifty-two population samples in thirty-two different

countries. Results showed that more than 50% of men had an average intake of sodium ranging from 150 to 199 $mmol/d$ and approximately 50% of women from 100 to 149 $mmol/d$ ⁽¹⁶⁾. Results of the Scottish survey in 2007 also showed higher urinary sodium excretion among men, 160 $mmol/d$ *v.* 117 $mmol/d$ in women. The results of another survey in Finland (2002) showed higher urinary sodium excretion among men, 170 $mmol/d$ *v.* 130 $mmol/d$ in women⁽³³⁾. We concluded that sodium excretion in the Slovene population was higher than in the majority of countries included in the INTERSALT studies and other European countries.

According to the excretion expressed in grams of salt, salt intake was determined in our study to be 11.3 ($SD\ 4.9$) g/d (Table 1). Dahl⁽³⁴⁾ noted that daily intakes of sodium (salt) varied considerably across population groups, from a low of 4 g salt/d (sodium: 1.56 g/d , 68 $mmol/d$) among Alaskan Inuit to 27 g salt/d (sodium: 10.6 g/d , 460 $mmol/d$) in the Akita prefecture in north-east Japan. American men had intakes averaging 10 g salt/d (sodium: 3.91 g/d , 170 $mmol/d$). It has been estimated in the INTERSALT study that salt intakes in Belgium, Denmark and the Netherlands were between 8 and 9 g/d , and in Finland, Italy and Portugal intakes were between 9 and 12 g/d . In men, daily intakes of salt over 11.7 g/d were estimated in Canada, Hungary, India, Italy, Portugal and Korea^(16,35).

As presented in Table 1, we found higher salt intakes in men (13.0 ($SD\ 5.1$) g/d) than in women (9.9 ($SD\ 4.3$) g/d), reflecting differences in energy needs⁽⁹⁾ and energy intake⁽³⁶⁾.

We found that the intake of salt significantly increased with increasing BMI (Fig. 4). Results from the INTERSALT study indicate that adjusting for BMI has an important effect on the association of sodium and sodium-potassium ratio with blood pressure; they also indicate that each of the three variables is related to blood pressure across the BMI range⁽⁸⁾. We assume that participants with higher salt intake in our study tended to have higher energy intake.

Grzegorzczak *et al.*⁽³⁷⁾ observed an age-related decrease in salt taste acuity. Drewnowski *et al.*⁽³⁸⁾ found that age-related deficits in salt taste perception are said to increase preferences for salty foods, thereby potentially leading to greater sodium intakes. We found in our study that salt intake increased slightly but not significantly with increasing age, while other studies indicated that sodium intake in adults appears to be slightly lower after the age of 50 years than at younger ages⁽³⁹⁾. Otherwise, daily energy needs in adults decrease with increasing age⁽⁹⁾.

Considering that 90% of the ingested sodium is excreted in the urine and the remaining 10% is excreted through the skin and faeces⁽¹⁹⁾, we were able to estimate the total daily intake of salt in Slovene adults. The estimated total daily salt intake was therefore 14.3 g/d in men and 11.0 g/d in women (mean 12.4 g/d). We did not find statistically significant regional differences in salt intake.

Strengths and limitations

We used the 'gold standard' 24 h urine collection to estimate salt intake. Reliability and completeness were ascertained through rigorous checks and urinary creatinine excretion. The sampling frame was population-based and the sampling was random in order to limit bias and increase the ability to generalise the inputs. However, due to the pilot nature of the study, the sample size was small, and therefore true estimates may vary from the point estimate. In addition, the response rate was low. Presumably, information provided to participants in the invitation about high salt intake as a risk factor for non-communicable chronic diseases may have influenced the results.

Implications

Total salt intake in Slovene adults significantly exceeds the WHO upper limit by 140%. Increasing salt intake is associated with increased risk for hypertension. The prevalence of high blood pressure (above 140/90 mmHg) in the Slovene adult population aged 25 to 64 years is 39.6%⁽⁴⁰⁾, and CVD are the leading cause of death in Slovenia (40% of all deaths)⁽²⁾.

Based on data from a household budget survey carried out by the Statistical Office of the Republic of Slovenia, it was estimated that for the period 2000–2005 the average presence of salt in purchased foods was 5.6 g/person per d, not accounting for ready-made meals, most semi-prepared foods or adding salt during cooking and at the table. The largest contributors to salt availability were breads and bakery products (2.1 g/person per d), meat products (1.5 g/person per d) and cheeses (0.3 g/person per d)^(41,42). Furthermore, 20% of Slovenian adult population adds salt at the table⁽⁴⁰⁾. According to the results of studies in Western Europe, processed, ready-made and semi-prepared foods are the main sources of salt consumed and represent as much as 80% of salt consumed⁽⁴³⁾. Similarly, we also consider these foods and adding salt during cooking and at the table to be the main sources of salt intake in Slovenia. In Slovenia, we are still in the initial stages of planning a national programme for reducing salt intake. Therefore, targeted monitoring of the sources of salt intake in the Slovene population is required.

In Slovenia, we adopted the joint WHO/FAO recommendations that state that the population nutrient intake goal for salt should be <5 g/d. The present results show that these targets are far from being reached in Slovenia. A national programme for reducing salt intake needs to be implemented through combined efforts of national campaigns and initiatives, involvement of industry to achieve reformulation of food production, and intensive interventions suited to primary care or population prevention programmes, as well as consumer education. The most important step in reducing salt intake is developing labelling of the salt content in foods to help consumers choose foods with less salt⁽¹⁸⁾. All effective strategies are encouraged to reach the upper recommended salt intake

level, which is less than 5 g/d according to the WHO⁽¹²⁾ and the Nutrition Action Plan for Slovenia⁽²⁾.

Total salt intake in Slovene adults significantly exceeds the WHO upper limit. Therefore, it is clear that implementation of a national programme for reducing salt intake should also focus on collaboration with the food industry and on production of low-salt or reduced-salt foods.

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