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ORIGINAL ARTICLE

Estimate of total salt intake in two regions of Belgium through analysis of sodium in 24-h urine samples

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Objectives: To evaluate total salt intake in the adult population through an analysis of sodium in 24-h urine samples in two regions of Belgium.
Methods: Urine samples were collected over 24 h from participants and they had to complete a specific questionnaire about salt intake afterwards. Sodium and creatinine concentrations were analysed in these samples.
Subjects: The target population comprised adults aged 45–65 years in the region of Ghent and Liege. A total of 123 and 157 volunteers from Ghent and Liege, respectively, were included in the study.
Results: The mean creatinine level in Flanders ($n=114$) amounted to 0.173 ± 0.035 mmol/kg/day, whereas in the Walloon region ($n=135$) it amounted to 0.161 ± 0.036 mmol/kg/day, after the exclusion of subjects with incomplete urine collection. Intake of sodium in Flanders ($n=114$) was 4.29 ± 1.29 g/day, whereas in the Walloon region ($n=135$) it was 3.94 ± 1.44 g/day. In both regions, sodium intake in men was higher than in women.
Conclusion: Salt intake was more or less twice as high as the recommended intake. Salt intake as estimated from 24-h urine collections is substantially higher than that previously calculated on the basis of food consumption data. A salt reduction programme for Belgium is primordial.
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Introduction

Conclusive scientific evidence links excessive consumption of sodium with cardiovascular disease, gastric cancer, osteoporosis, cataract, kidney stones and diabetes (Cappuccio and MacGregor, 1997; He *et al.*, 1999; Cappuccio *et al.*, 2000; Nagata *et al.*, 2004; Strazzullo *et al.*, 2009; Wang *et al.*, 2009). Results of the National Health Interview Survey of 2004 show that the prevalence of high blood pressure, cardiovascular disease, diabetes, cataract, osteoporosis and all cancers in Belgium is, respectively, 10.9, 4.3, 3.4, 1.2, 0.8 and 0.7% for men and 13.6, 3.1, 3.6, 2.5, 5.6 and 1.3% for women (Bayingana *et al.*, 2006).

Results of the Belgian National Food Consumption Survey in the population of 15 years or older show that the mean sodium intake of the Belgian adult population (>18 years), adjusted for age and gender, was 2.7 ± 1.0 g/day in 2004. Only 23.3% of the Belgian population complied with the WHO recommendation of ingesting <2 g of sodium/day. The threshold of 3.5 g/day (Superior Health Council) was met by 81.2% of the population (Vandevijvere and Van Oyen, 2008). A problem with food consumption surveys is that consumption of table salt and that of salt used in cooking are often strongly underestimated. In the United Kingdom, it has been shown that table salt and salt added during cooking contribute 11%, whereas food processing contributes 77% to the total sodium intake of the population (Mattes and Donnelly, 1991). Even though the results of the

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national survey underestimate total sodium intake, these data show that more or less 75% of the Belgian population exceeded the WHO threshold for sodium intake (Vandevijvere and Van Oyen, 2008). Therefore, salt reduction was included as one of the priorities by the Minister of Health in its National Nutrition and Health Plan (NNHP) for Belgium for the period 2005–2010.

Estimates based on food diaries, 24-h recalls and food frequency questionnaires tend to underestimate sodium intakes as compared with intakes estimated from duplicate diets or 24-h urine collections (Leiba *et al.*, 2005; Olafsdottir *et al.*, 2006; Reinivuo *et al.*, 2006). Spot urine samples are not representative for whole-day urine excretion because of variations in sodium concentration over the day. Therefore, 24-h urine collection is necessary and is the gold standard for determining sodium and salt intake in the population.

The overall aim of this study was to evaluate total salt intake in the adult population (45–65 years) through analysis of sodium in 24-h urine samples in two regions of Belgium (Ghent and Liege) and consequently to estimate salt consumption both through intake of (processed) foods and through intake of household salt and salt used in cooking.

Materials and methods

Study design

The European Food Consumption Validation (EFCOVAL) study validated a duplicate 24-h dietary recall in five selected countries (Belgium, region of Flanders included) against biomarkers of dietary intake. In Belgium, this cross-sectional study took place in Ghent during the period December 2007–March 2008. The data were collected by the EFCOVAL investigators and were made available for this publication by the EFCOVAL consortium. Views expressed in this paper are those of the authors and may not reflect those of the EFCOVAL Consortium. For the purpose of this study, only the collected 24-h urine samples were used. Sodium concentrations in these samples were analysed in August 2009. A specific questionnaire about salt consumption was sent to all participants after completion of the survey in the period March–June 2009.

In the Walloon region, a specific survey for the purpose of this study was organized in Liege during the period February–September 2009. Only 24-h urine samples were collected. A specific questionnaire about salt consumption was completed by the participants on submission of their urine sample. The urine samples were analysed in August 2009.

Both studies were approved by the medical ethical committee of the University of Ghent and the University of Liege.

Subjects

The target population comprised all adults aged 45–65 years in the region of Ghent and Liege. In Flanders, subjects were recruited from Ghent and from the surrounding area by distribution of an invitation e-mail sent to the mailing list of the Faculty of Medicine and Health Sciences of Ghent University, and to staff of the Ghent University Hospital. Subjects were also recruited through distribution of flyers, random telephone calls and personal approaches, and by relatives, friends and colleagues. In the Walloon region, subjects were recruited from Liege and the surrounding area by distribution of an invitation e-mail sent to the mailing list of the Faculty of Biomedical sciences at the hospital of Liege. Further, this survey was publicized through the distribution of flyers and posters in professional health offices, pharmacies, libraries and factories in the surrounding area.

Subjects were excluded if they were unable or unwilling to comply with the study procedures, if they were unable to communicate in French or Dutch, had diabetes or a kidney disease, were currently taking diuretics, followed a prescribed medical dietary therapy, were pregnant/lactating or if they were living in the same household as an individual who already participated in the study. Immigrants speaking French or Dutch could participate in the study. Subjects who were expected to have disturbed absorption or excretion (coeliakie, lactose intolerance) were not included either. There was no recruitment of subjects from institutionalized places such as hospitals.

On recruitment of a subject, a screening questionnaire was used to check inclusion and exclusion criteria. After that, personal appointments were scheduled with the eligible subjects. A voucher was offered to the volunteers to motivate them for participation in the study. Participants were not reimbursed for travel expenses.

A substantial effort was put into place to have a proportional representation of gender and the different education levels in the final study samples. Data on education level were collected as a 157 proxy for socio-economic status and divided into six categories: only primary education, lower 158 secondary education (first 3 years), higher secondary education (last 3 years), higher education 159 (short or long type) excluding university, university, other education. Thereafter, these levels were regrouped into three categories: low, intermediate and high education level.

In Flanders, the data were used for the purpose of a validation study; a net sample of 60 men and 60 women was aimed at. Further, a net sample of 60 men and 60 women was aimed at in the Walloon region. According to a WHO report (World Health Organisation, 2007), to estimate sodium intake with a 95% confidence interval, a single 24-h urine collection from a sample population of 100–200 people is required. In both regions, an anticipated dropout percentage of 20% was taken into account.

Data collection

At the study centre, the participants received full explanation about the study and detailed instructions for the 24 h urine collection. They needed to complete an informed consent form. All urine, starting from waking up urine on day 1 (excluded) till (included) morning urine on day 2, was collected.

In the diary, subjects recorded the time of start and finish of urine collection, completeness of urine, use of specific medicines/supplements and possible performance of vigorous physical activity on the day of collection. On submission of the urine containers, the participants needed to complete a small questionnaire about the use of household salt. The subjects were weighed at the study centre.

In Liege, only a single 24-h urine sample was requested from the participants. In Flanders, two 24-h collections per subject were requested, one for each 24-h recall.

Before storage at the study centre, urine samples had to be weighed and mixed in order to have homogenized samples of known volume. Urine samples were put in boxes and stored in a −20 °C freezer.

Sample analysis

Creatinine and sodium concentrations were determined in the 24-h urine samples. The analyses were performed at the Wageningen University Department of Human Nutrition, according to standardized protocols and following high standards of quality control. Indirect potentiometry was carried out to determine sodium concentration, using the Synchron LX System(s) (2004b).

Completeness of 24 h urine collection was checked by analysing creatinine levels. The use of creatinine as a check on the completeness of 24-h urine collections is based on the assumption that excretion per kg body mass is constant (Bingham and Cummings, 1985). Creatinine was analysed using CREm on the Synchron LX system(s) (2004a). This methodology is a modification of the kinetic Jaffe reaction.

Data analysis

For Flanders, only the first 24-h urine collection from each participant was used in the calculations.

For each complete urine container, the weight of the empty container was subtracted from the weight of the filled container; further, the total quantity of collected urine was calculated. Sodium and creatinine concentration levels in g/l were calculated by multiplication of total mmol/l with the molecular mass, 23 g/mol for sodium and 113.12 g/mol for creatinine.

Sodium and creatinine excretion per day were calculated by multiplying the concentration per litre with the total quantity of urine collected over the day, expressed in litre. Intake of sodium was calculated by multiplying with the factor 100/95, because sodium excretion through urine is on average 95% of the intake. Intake of salt was calculated from the sodium intake by multiplying with factor 2.5 (gezondheidsraad, 2000).

Excretion per day of collection was taken as a basic assumption for the results. The collection day could deviate from 24 h on an individual basis.

For all supplements and medicines mentioned in the diary, the presence of sodium was evaluated.

Completeness of urine collection was assessed by (1) a question about the starting and ending time of the collection, (2) a question about possible losses of urine and (3) a question whether there were problems during collection.

To assess the adequacy of collection, the total amount of creatinine excreted (creatinine index) was calculated and had to be in the range of 20–26 mg/kg/day (0.177–0.230 mmol/kg/day) for men and 15–20 mg/kg/day (0.133–0.177 mmol/kg/day) for women (Stein, 1998). The concept of a normal range for serum creatinine concentration is actually a misnomer, as the normal serum creatinine concentration depends on muscle mass and renal function. Persons with marked obesity, ascites or anasarca excrete less creatinine per body weight, as their muscle mass represents a much smaller proportion of the weight compare with normal individuals. In normal or asthenic persons, normal body weight can be used (Stein, 1998).

Participants with a creatinine concentration below the normal value ($0.177 < ♂ < 0.230$ mmol/kg/day for men and $0.133 < ♀ < 0.177$ mmol/kg/day for women), in combination with a total urine collection of less than 1 l/day (Reinivuo *et al*., 2006), were excluded. Participants who stated in the diary that urine collection was incomplete, irrespective of the size of losses, were also excluded.

After exclusion of participants with incomplete 24-h urine collection, the distribution of sodium and salt intake was calculated for both regions separately. Owing to the small number of persons, no stratification was possible according to age group and education level.

Results and Discussion

The general characteristics of the Flemish ($n = 123$) and Walloon study population ($n = 157$) are shown in Table 1. The characteristics of urine collection in both regions are shown in Table 2. Through the screening questionnaire, persons suffering from diabetes or renal disease, or persons taking diuretics, were excluded beforehand. In all, 18.7% of Flemish and 25.5% of Walloon participants reported to suffer from another disease than mentioned in the exclusion list: In Flanders, four persons reported having a too high blood pressure and three persons reported suffering from cardiac problems; in the Walloon region, three persons reported suffering from cardiac problems.

The results of 114 Flemish respondents were available for further analyses. In total, nine persons were excluded because of assumed incomplete urine collection: urine loss during the day as stated in the diary and/or persons having creatinine excretion below the normal values, in combination with a urine volume of less than one litre. The results of

135 Walloon respondents were available for further analyses. One person was excluded because of unknown weight, one person was excluded because of unknown urine volume and 20 persons were excluded because of assumed incomplete urine collection: urine loss during the day as stated in the diary and/or persons having creatinine excretion below normal values, in combination with a urine volume of less than one litre.

Table 1 General characteristics of the study population in Ghent (Flanders) and in Liege (Walloon region)

	Flanders		*Walloon region*	
	Men (n = 63)	*Women* (n = 60)	*Men* (n = 76)	*Women* (n = 81)
Mean age (years)	54.5 ± 5.5	54.9 ± 5.0	54.7 ± 5.4	54.6 ± 5.2
Age (n)				
44–50	15	13	18	20
51–55	16	18	23	26
56–60	23	20	21	24
61–65	9	9	14	11
Education level (n)				
Low	10	10	20	19
Intermediate	15	15	34	21
High	38	35	22	38
Mean Weight (kg)	84.1 ± 13.4	67.6 ± 12.5	83.2 ± 13.7[a]	68.1 ± 12.4[b]

[a]1 missing value.
[b]2 missing values.

The mean creatinine level in Flanders ($n = 114$) amounted to 0.173 ± 0.035 mmol/kg/day (0.191 ± 0.030 mmol/kg/day for men and 0.154 ± 0.029 mmol/kg/day for women), whereas in the Walloon region ($n = 135$) it amounted to 0.161 ± 0.036 mmol/kg/day (0.184 ± 0.027 mmol/kg/day for men and 0.138 ± 0.028 mmol/kg/day for women), after exclusion of subjects with incomplete urine collection (Table 3).

Intake of sodium in the Flemish region ($n = 114$) was 4.29 ± 1.29 g/day, whereas salt intake amounted to 10.90 ± 3.80 g/day. Intake of sodium in the Walloon region ($n = 135$) was 3.94 ± 1.44 g/day, whereas salt intake amounted to 10.03 ± 3.66 g/day. In the Flemish region, only one person had a salt intake lower than 5 g/day, whereas in the Walloon region 10 persons had a salt intake lower than 5 g/day, which is the WHO recommended upper level of salt intake. Salt intake in men was higher than in women in both regions (Table 3).

The results of this study clearly indicate that average salt consumption as estimated from 24-h urine collections is substantially higher than that previously suggested by food consumption surveys using different methods (Vandevijvere and Van Oyen, 2008).

Data from the national food consumption survey show that mean sodium intake (s.e.) in the 45- to 65-year age group ($n = 1312$) amounted to 2.7 ± 0.1 g/day, which is more or less the same as the sodium intake level in the general adult population (Vandevijvere and Van Oyen, 2008). Ghent and Liege were both selected as municipality to participate in this survey. Sodium intake in the 45- 65-year age group in Ghent ($n = 28$) was 2.5 ± 0.32 g/day, whereas sodium intake

Table 2 General characteristics of urine collection in Ghent (Flanders) and in Liege (Walloon region)

	Flanders		*Walloon region*	
	Men (n = 63)	*Women* (n = 60)	*Men* (n = 76)	*Women* (n = 81)
Complete urine collection in opinion of subject (diary) (*n*)	61	56	71	75
Loss of urine according to diary (*n*)	2	4	4	6
Mean volume of urine collection (ml)	2120.6 ± 937.4	2383.4 ± 1157.5	1872.24.3 ± 750.75	2023.13 ± 811.17[a]
Volume (n)				
< 1000 ml	4	4	5	6
(1000–2000 ml)	29	20	43	40
(2000–3000 ml)	19	19	20	24
(3000–4000 ml)	7	13	8	10
> 4000 ml	4	4	0	1
Use of supplements (n)	11[a]	18[b]	9	22
With sodium	2	2	3	4
With iodine	1	1	0	2
Use of medicine (n)	19[c]	25[d]	35	33
With sodium	14	14	15	20

[a]1 missing value.
[b]2 missing values.
[c]2 missing values.
[d]1 missing value.

Table 3 Creatinine level (mmol/kg per day) and salt intake (mean, P50, P75, P95) in both the study populations after excluding incomplete urine collections

	Flanders		Walloon region	
	Men (n = *60*)	*Women* (n = *54*)	*Men* (n = *66*)	*Women* (n = *69*)
Creatinine level (mmol/kg/day)				
Mean (s.d.)	0.191 ± 0.030	0.154 ± 0.029	0.184 ± 0.027	0.138 ± 0.028
P50	0.194	0.151	0.183	0.139
P75	0.211	0.170	0.202	0.160
P95	0.226	0.202	0.239	0.196
Salt intake (g/day)				
Mean (s.d.)	11.79 ± 4.13	9.91 ± 3.15	11.49 ± 3.51	8.63 ± 3.26
P50	11.07	9.56	11.6	8.16
P75	14.81	11.23	13.58	10.62
P95	19.61	15.88	17.4	15.7

in Liege ($n = 48$) amounted to 2.2 ± 0.02 g/day in 2004. These values represent the consumption of sodium, without taking into account salt added during preparation and consumption of meals.

In Flanders, two 24-h urine collections were obtained from the subjects. The mean ($n = 107$) sodium intake for the second urine collection, after exclusion of assumed incomplete urine collections, was found to be 4.58 ± 1.67 g/day (4.04 ± 1.66 g/day for women and 5.06 ± 1.55 g/day for men). The degree of concordance between the first and second urine collection was found to be fair ($\rho = 0.43$; $P < 0.001$). Surprisingly, the degree of concordance was much better for women ($\rho = 0.61$; $P < 0.001$) than for men ($\rho = 0.22$; $P = 0.1$).

From the questionnaire, it was found that, in Flanders, 22.12% of respondents do not use salt for cooking and do not add salt during consumption, 10.58% do not use salt for cooking but add salt during consumption, 63.46% use salt during cooking but do not usually add salt during consumption and 3.85% use salt in cooking and add salt during consumption afterwards. In the Walloon region, these percentages are 5.7, 5.1, 79.1 and 10.1%, respectively. Most consumers seem to add salt during preparation of meals, and a few also add salt during consumption of meals.

Because of the current obesity epidemic, the occurrence of greater salt sensitivity in overweight/obese individuals and the possibility that larger salt intake is partly a consequence of higher calorie intake, the association between BMI and salt intake was also investigated in Flanders. In the Walloon region, no data on height were available. The association found was fair ($\rho = 0.36$; $P < 0.001$) and differed substantially between men ($\rho = 0.39$; $P < 0.01$) and women ($\rho = 0.23$; $P = 0.09$).

An important limitation of this study is that the subjects were not recruited in a way to provide a country-specific representative sample. Obtaining a representative sample is difficult because of two reasons: lack of sufficient financial means (a representative sample would increase costs for staff, transport and recruitment significantly), and high burden for the respondents (which makes recruitment of volunteers more appropriate). A major drawback of working with volunteers is the introduction of a 'healthy volunteer bias'. Further, completeness of 24 h urine collection was checked by analysing creatinine on the basis of the assumption that excretion per kg body mass is constant. In literature, it was found that PABA is a more sensitive and reliable verification of the completeness of 24-h urine collections than is creatinine (Bingham and Cummings, 1985; Bingham and Cummings, 1986), but more expensive and therefore it could not be used in this study.

Conclusion

Salt intake is more or less twice as high as the recommended intake. Men consume more salt than do women. These results are in line with the results of salt intake from the national food consumption survey, although salt intake is substantially higher when calculated on the basis of 24-h urine samples. A salt reduction programme for Belgium is primordial.

Conflict of interest

The authors declare no conflict of interest.

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