British Journal of Nutrition (2015), **113**, 488–497
doi:10.1017/S0007114514003791

Reporting accuracy of population dietary sodium intake using duplicate 24 h dietary recalls and a salt questionnaire

Willem De Keyzer[1]*, Marcela Dofková[2], Inger Therese L. Lillegaard[3], Mieke De Maeyer[4], Lene Frost Andersen[5], Jirí Ruprich[2], Irena Řehůřková[2], Anouk Geelen[6], Pieter van 't Veer[6], Stefaan De Henauw[1,4], Sandra Patricia Crispim[7], Evelien de Boer[8], Marga Ocké[8], Nadia Slimani[7] and Inge Huybrechts[4,7]

[1]*Department of Bio- and Food Sciences, University College Ghent, Ghent, Belgium*
[2]*Center for Health, Nutrition and Food, National Institute of Public Health in Prague, Brno, Czech Republic*
[3]*Norwegian Scientific Committee for Food Safety, Oslo, Norway*
[4]*Department of Public Health, Ghent University, Ghent, Belgium*
[5]*Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway*
[6]*Division of Human Nutrition, Wageningen University, Wageningen, The Netherlands*
[7]*Dietary Exposure Assessment group, International Agency for Research on Cancer (IARC), Lyon, France*
[8]*Centre for Nutrition, Prevention and Health Services, National Institute for Public Health and the Environment (RIVM), Bilthoven, The Netherlands*

(Submitted 3 July 2014 – Final revision received 17 October 2014 – Accepted 22 October 2014 – First published online 13 January 2015)

Abstract

High dietary Na intake is associated with multiple health risks, making accurate assessment of population dietary Na intake critical. In the present study, reporting accuracy of dietary Na intake was evaluated by 24 h urinary Na excretion using the EPIC-Soft 24 h dietary recall (24-HDR). Participants from a subsample of the European Food Consumption Validation study (*n* 365; countries: Belgium, Norway and Czech Republic), aged 45–65 years, completed two 24 h urine collections and two 24-HDR. Reporting accuracy was calculated as the ratio of reported Na intake to that estimated from the urinary biomarker. A questionnaire on salt use was completed in order to assess the discretionary use of table and cooking salt. The reporting accuracy of dietary Na intake was assessed using two scenarios: (1) a salt adjustment procedure using data from the salt questionnaire; (2) without salt adjustment. Overall, reporting accuracy improved when data from the salt questionnaire were included. The mean reporting accuracy was 0·67 (95 % CI 0·62, 0·72), 0·73 (95 % CI 0·68, 0·79) and 0·79 (95 % CI 0·74, 0·85) for Belgium, Norway and Czech Republic, respectively. Reporting accuracy decreased with increasing BMI among male subjects in all the three countries. For women from Belgium and Norway, reporting accuracy was highest among those classified as obese (BMI ≥30 kg/m^2: 0·73, 95 % CI 0·67, 0·81 and 0·81, 95 % CI 0·77, 0·86, respectively). The findings from the present study showed considerable underestimation of dietary Na intake assessed using two 24-HDR. The questionnaire-based salt adjustment procedure improved reporting accuracy by 7–13 %. Further development of both the questionnaire and EPIC-Soft databases (e.g. inclusion of a facet to describe salt content) is necessary to estimate population dietary Na intakes accurately.

Key words: Diet surveys: Self-reports: Biological markers/urine: Dietary sodium: European Food Consumption Validation

The current WHO guidelines strongly recommend a reduction in Na intake to <2 g/d (i.e. <5 g salt/d)[1]. There is conclusive evidence that reduction in Na intake reduces blood pressure[2–5]. The relationship between Na consumption and the risk of CVD and stroke is less clear than that of hypertension. For example, a systematic review of randomised controlled trials has found no relationship between Na intake and CVD risk[6]; however, a meta-analysis of thirteen cohort studies has concluded that there is a direct relationship between increased Na consumption and the subsequent risk of CVD and stroke[7].

Data from an international epidemiological study on dietary factors in the aetiology of unfavourable blood pressure (the INTERMAP study) showed that sources of dietary Na can vary considerably. For instance, processed foods contribute heavily to Na intake in the USA and the UK (70–95 %), whereas in China, most dietary Na intake (76 %) is from salt added during home cooking[8]. Another study, in which Li

Abbreviations: 24-HDR, 24 h dietary recall; EFCOVAL, European Food Consumption Validation; FCT, food composition table; PABA, *para*-aminobenzoic acid.

* **Corresponding author:** Dr W. De Keyzer, email willem.dekeyzer@hogent.be

was used as a marker to assess the intake of household salt, has shown that the median contribution of household salt was 8–10 % of the total salt intake in a Danish population[9].

In general, 24 h urine collection is considered to be the most reliable method to evaluate salt intake[10,11]. However, the 24 h urinary excretion method does not account for Na loss other than via the kidneys and will, therefore, tend to slightly underestimate true Na intake depending on the amounts excreted via sweat[12]. Although the 24 h urine collection method is not prone to reporting biases, participant burden is high and collections must be complete to ensure that excretion estimates are not biased[10]. Available methods to verify completeness of urine collections include (1) the use of a diary for participants to report any urine voiding not collected; (2) recovery of *para*-aminobenzoic acid (PABA)[13]; (3) a creatinine index of observed-to-expected urinary creatinine excretion[14]. Although the creatinine-based identification method of incomplete urine collections is frequently used, previous findings have shown that the creatinine index is an unreliable marker for detecting incomplete urine collections when compared with an internal standard such as PABA[15].

Given the important health-associated risks of high Na intakes, monitoring of Na consumption is essential and should be integrated in national surveillance programmes. There is a European consensus that two non-consecutive 24 h dietary recalls (24-HDR) using EPIC-Soft are the preferred method for estimations of Na intake at the population or group level[16]. Although the methods for collecting food consumption data have been improved over time, validation studies have shown that there is underestimation of protein (2–13 %) and K (4–17 %) intakes[17]; however, the bias is comparable across European countries[18]. To date, the reporting accuracy of dietary Na intake has not been assessed using the EPIC-Soft 24-HDR. Therefore, the objective of the present study was to assess the estimated dietary Na intake from self-reported dietary recalls using EPIC-Soft with 24 h urinary Na excretion. In addition, a salt adjustment procedure, using data from a questionnaire on the discretionary use of salt during food preparation or at the table, was evaluated to assess reporting accuracy.

Materials and methods

Design

The present study was performed as part of the European Food Consumption Validation (EFCOVAL) study that was completed in five European countries. The EFCOVAL study aimed at further developing and validating the use of repeated 24-HDR using the EPIC-Soft to assess the intake of foods, nutrients and potentially hazardous chemicals for surveillance purposes relevant to health and safety policies in Europe[19]. The fieldwork was performed from October 2007 to April 2008.

At the beginning of the study, subjects had their body weight (kg) and height (cm) measured at the study centres before the first urine collection. Then, a 24-HDR and a 24 h urine collection were obtained, covering the same reference day. Subjects were aware of the days of data collection but not aware of the purpose of the interviews. The second recall and urine collection were obtained at least 1 month after the first one.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Ethical committees of each participating country involved in the data collection. Written informed consent was obtained from all the subjects.

Subjects

The study group comprised a subsample of healthy European adults aged 45–65 years who participated in the EFCOVAL study. Data for reporting accuracy of population dietary Na intake were collected in three European countries: Belgium, Czech Republic and Norway. Taking into account an anticipated dropout of 20 % and aiming at a net sample of fifty per stratum, a minimum of sixty men and sixty women were recruited per country (n 360). Subjects were recruited by convenience sampling through advertisements (newspapers and websites) and mailing lists, among others, and we aimed to include at least ten men and ten women in each of the three predetermined categories of education level (low, intermediate and high) per country. Exclusion criteria included the following: use of diuretics; simultaneous participation in another study; pregnancy or lactation; having diabetes mellitus or a kidney disease. In addition, because of PABA administration during urine collections, use of sulphonamide-based antibiotics or acetaminophen painkillers (e.g. paracetamol) was not allowed, and subjects who were hypersensitive to sulphonamides or PABA were also excluded.

Dietary sodium

The two 24-HDR were assessed using the EPIC-Soft software (version 9.16; International Agency for Research on Cancer). The structure and standardisation procedure of EPIC-Soft have been described elsewhere[20,21]. Briefly, EPIC-Soft is a computer-assisted dietary intake assessment tool that follows standardised steps when describing, quantifying, probing and calculating food intakes across countries[20]. A concept of facets (questions: e.g. source) and descriptors (answer options: e.g. cow, goat, sheep and pork) is used to describe the foods and recipes recalled during the 24 h recall interview. The following two modes of administration were used: one by phone and one face-to-face at the centre. The order of the administration mode and the day of the week were randomly allocated among the subjects. Interviewers in each centre were nutritionists or dietitians who were trained in interviewing skills and working with EPIC-Soft in the context of a validation study. It is noteworthy that the EPIC-Soft versions used in the EFCOVAL study did not include any particular questions regarding Na content/intake (no facet was dedicated to salt content of specific foods/recipes).

The methods of the estimation of portion size included household measures, weight/volume, standard units and portions, drawings of bread shapes and photographs. Given the

absence of harmonised recent food composition tables (FCT) for all the three countries under study, Na contents in foods were calculated using country-specific FCT[22–24]. For the Czech Republic, a FCT was compiled for EFCOVAL purposes by using the composition of most foods based on the Slovakian tables because national data were lacking[25].

To calculate dietary Na intake, two different scenarios were used. First, Na was calculated using Na concentrations reported in country-specific FCT[22,24,25], i.e. only Na naturally present in foods or Na added during food processing reported as such in the FCT was counted (SODIUM scenario). Second, for prepared food items (e.g. meat, fish, potatoes and cooked vegetables), Na contents were increased to reflect Na levels of foods prepared using salt (SODIUMSALT scenario). For Belgium, the amounts of salt used for adding were extracted from the US Department of Agriculture National Nutrient Database for Standard Reference[26], and for the Czech Republic, local salt addition factors were available and used in the present analysis. For Norway, salt addition factors were not available and, therefore, not used in the present analysis.

Questionnaire on salt use

After the collection of the two 24-HDR, participants were mailed and requested to complete a short questionnaire on salt use that asked whether they usually use salt ((a) No, salt is not used, neither during preparation of meals nor by adding salt during consumption; (b) Yes, salt is added to meals during consumption, not during preparation of meals; (c) Yes, salt is used during preparation of meals, no salt is added to meals during consumption; (d) Yes, salt is used during preparation of meals and added to meals during consumption). In addition, respondents were asked about the frequency of salt addition to their meals during consumption ((w) never; (x) occasionally; (y) often; (z) always).

Urinary sodium

All subjects were carefully instructed to keep two 24 h urine collections according to a standardised protocol. Subjects were asked to urinate upon rising in the morning; this micturition was completely discarded. Subsequently, all urine produced during the next 24 h was collected up to, and including, the first voiding of the following day. Subjects were provided a diary to record the time of rising, medication use and possible deviations (e.g. missing urine) from the urine collection protocol. To verify the completeness of urine collections, an 80 mg PABA tablet (PABAcheck; Laboratories for Applied Biology) was taken three times during the day. After approximately 1 month, the same procedure was repeated, so every subject yielded two 24 h urine collections. At the study centre, urine samples were weighed and well mixed by study site staff before aliquoting into 10 ml cryostorage tubes. Aliquots of the 24 h urine samples were frozen at −20°C until shipment on dry ice to the central laboratory at the Division of Human Nutrition of Wageningen University. PABA was measured using the colorimetric diazo-coupling method described by Bingham & Cummings[13]. The recoveries of PABA below 50 % were treated as incomplete collections and those between 50 and 85 % were proportionally adjusted to 93 % of PABA recovery[27]. Na concentrations were determined by indirect potentiometry on a Synchron LX20 (Beckman Coulter). Excretion values of Na were calculated by multiplying with the factor 100/90, because on average 90 % of Na consumed is excreted via the urine[12]. The EFCOVAL protocol for specimen collection, storage and transport was used by all the study centres.

Statistical analyses

Statistical analyses were performed using IBM SPSS Statistics for Windows (IBM Corporation Released 2011, version 20.0; IBM Corporation). Because of methodological differences between the countries in calculating dietary Na intake, country-specific data are presented here.

The reporting accuracy of dietary Na intake was assessed using two scenarios. In the first scenario, no data processing step was applied with respect to salt addition. Therefore, Na values were aggregated to calculate total Na intake. The second scenario presented Na intake after salt adjustment based on the respondent's answer to a question about the use of salt during food preparation or at the table. For respondents who did not add salt to their food (answer option (a)), salt adjustment was not performed and total Na values equalled those from the first scenario. Respondents who indicated that usually salt is used during cooking (answer options (c) and (d)), total Na intake was calculated by summing up the Na levels of foods prepared using salt (SODIUMSALT scenario). Finally, for respondents who indicated that, in general, salt is added to their meal during consumption using a salt shaker (answer options (b) and (d)), a standard amount of Na was added to reflect salt addition. The amounts of Na added were based on the respondent's answer to the question on the frequency of salt added to meals ((w) 0 mg; (x) 25 mg; (y) 50 mg; (z) 100 mg).

Dietary Na intake (DRNA) and urinary Na excretion (URNA) were log-transformed to improve the distribution towards normality. To account for serial correlations between individual subject dietary recalls and between individual urinary excretions, sample within-subject variances and standard deviations were estimated from a linear mixed model of dietary Na intake and urinary Na excretion with random intercepts and all fixed effects for up to two dietary recalls and urinary excretions. Within sex and country, means and 95% CI for 24 h Na intakes were estimated using the estimated marginal means subcommand. Logarithmic means were back-transformed to geometric means on the original scale. Reporting accuracy was calculated from subgroup geometric means as a ratio of dietary Na:excreted urinary Na (DRNA:URNA).

The 95 % confidence limits of the log ratio were calculated by adding

$$\pm 1{\cdot}96\sqrt{\frac{\sigma^2_{\text{wDRNA}}}{d}+\frac{\sigma^2_{\text{wURNA}}}{d}-2r\frac{\sigma^2_{\text{wDRNA}}\sigma^2_{\text{wURNA}}}{d}},$$

where σ_{wDRNA} is the within-subject standard deviation for the log of 24 h dietary Na intake; d is the number of days of

British Journal of Nutrition

dietary Na intake; σ_{wURNA} is the within-subject standard deviation for the log of urinary Na excretion; and r is the correlation between the log of dietary and urinary Na[28]. On the original scale, the 95% confidence limits are given by the exponential of the limits on the log scale.

Assuming independence for the two 24-HDR and the two urinary Na excretion measurements, σ_{wDRNA} and σ_{wURNA} can be estimated as one-half of the dietary Na intake sample variance of $(\log_{DRNA1} - \log_{DRNA2})$ and one-half of the urinary Na excretion sample variance of $(\log_{URNA1} - \log_{URNA2})$, respectively, in a design with two dietary Na intakes ($d = 2$) and two urinary Na excretion measurements per subject[29].

Results

The net study sample comprised fifty-eight to sixty-three subjects for each sex and country stratum, resulting in a total of 183 males and 182 females. Demographic characteristics of the study sample are presented in Table 1. Of these subjects, 57% were highly educated. There was a significant difference in education level across the countries for women ($\chi^2 = 13{\cdot}204$, df = 4; $P = 0{\cdot}01$). More women (58%) than men (29%) were considered normal weight (BMI 18·5–24·9 kg/m^2).

All participants (n 365) collected their urine the first time, but two participants failed to perform the second collection, resulting in a total of 728 urine samples. Samples with PABA recoveries <50% were treated as incomplete and excluded from the data analysis (n 9). Specimens with PABA recovery between 50 and 85% (n 57) had their urinary concentrations proportionally adjusted to 93% of PABA recovery. Recoveries >85% were included in the data analyses without adjustments (n 662).

Geometric means for Na measured by the urinary biomarker and calculated based on self-reports from the EPIC-Soft 24-HDR are presented in Table 2. The mean dietary Na, calculated by using individual subject means for the two recalls from Belgium, represented 61 and 59% of the mean Na biomarker for men and women, respectively. The mean dietary Na was 75 and 70% for Norway and 67 and 66% for the Czech Republic, for men and women, respectively. Reporting accuracy was higher after the data were adjusted for salt intake during preparation and consumption of foods. Reporting accuracy increased by 7% for Belgium, 1% for Norway and 13% for the Czech Republic.

Reporting accuracy was highest among normal-weight subjects, except for obese women from Belgium and Norway where reporting accuracy was highest among obese subjects (Table 3). Among the normal-weight subjects from Belgium and Norway, reporting accuracy was higher for men than for women (0·80 and 0·69; 0·86 and 0·73, respectively). For the Czech Republic, reporting accuracy was similar for both normal-weight men and women (0·84 and 0·87, respectively). No consistent differences were found between educational

Table 1. Demographic characteristics of the study sample (n 365)*
(Mean values and standard deviations or percentages)

	Belgium		Norway		Czech Republic	
	Men (n 63)	Women (n 60)	Men (n 62)	Women (n 62)	Men (n 58)	Women (n 60)
Age (years)						
Mean	54·5	54·9	54·1	53·7	55·0	54·8
SD	5·5	5·0	5·9	6·0	6·9	6·1
Weight (kg)						
Mean	84·1	66·9	85·7	68·4	85·6	66·7
SD	13·3	11·9	9·9	11·4	13·3	9·7
Height (cm)						
Mean	176	163	180	166	175	164
SD	7·0	6·7	7·2	6·8	6·1	6·1
BMI (kg/m^2)						
Mean	27·2	25·0	26·4	24·8	27·8	24·9
SD	3·6	4·1	2·5	3·7	4·2	3·9
Age (%)						
45–54 years	46	48	50	56	50	52
55–65 years	54	52	50	44	50	48
Education (%)						
Low	16	17	3	16	21	17
Intermediate	24	25	31	19	24	47
High	60	58	66	65	55	37
BMI category (%)						
Normal weight (18·5–24·9 kg/m^2)	27	62	29	56	31	55
Overweight (25–29·9 kg/m^2)	56	25	63	32	41	35
Obese (≥30 kg/m^2)	17	13	8	11	28	10
Salt use (%)						
No	26	18	6	8	2	7
Only during consumption	9	12	6	15	0	2
Only for preparation	57	71	49	44	69	63
Both for preparation and during consumption	8	0	40	33	29	28

* Some percentages do not total 100 because of rounding.

Table 2. Daily dietary sodium intake and urinary excretion measured in male and female subjects according to country
(Geometric means* and 95 % confidence intervals)

	Belgium (*n* 123)				Norway (*n* 124)				Czech Republic (*n* 118)			
	Men		Women		Men		Women		Men		Women	
	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI
DRNA – SODIUM†												
Recall no. 1 (mg/d)	2904	2600, 3245	2274	2028, 2550	3585	3206, 4009	2481	2218, 2774	4141	3685, 4652	2890	2580, 3237
Recall no. 2 (mg/d)	2949	2640, 3295	2458	2188, 2761	3479	3106, 3896	2356	2105, 2637	4081	3632, 4585	2936	2616, 3295
Mean recall (mg/d)	2927	2676, 3200	2365	2155, 2595	3532	3226, 3867	2418	2209, 2646	4111	3742, 4516	2913	2656, 3194
DRNA – SODIUMSALT‡												
Recall no. 1 (mg/d)	3225	2904, 3580	2576	2312, 2870	3618	3256, 4020	2524	2272, 2805	4906	4395, 5476	3470	3117, 3862
Recall no. 2 (mg/d)	3256	2932, 3615	2703	2422, 3017	3512	3156, 3909	2397	2156, 2666	4840	4336, 5402	3558	3191, 3967
Mean recall (mg/d)	3240	2975, 3529	2639	2414, 2884	3564	3269, 3887	2460	2256, 2682	4873	4454, 5331	3513	3217, 3837
URNA§												
Biomarker no. 1 (mg/d)	4507	4158, 4886	3879	3570, 4214	4924	4542, 5338	3435	3169, 3724	6203	5702, 6748	4339	3997, 4711
Biomarker no. 2 (mg/d)	5102	4709, 5528	4076	3748, 4433	4469	4118, 4851	3494	3221, 3791	6055	5566, 6588	4508	4148, 4900
Mean biomarker (mg/d)	4796	4484, 5129	3976	3709, 4263	4691	4383, 5021	3465	3238, 3708	6129	5712, 6576	4423	4128, 4739
Reporting accuracy‖												
SODIUM	0·61	0·57, 0·66	0·59	0·55, 0·64	0·75	0·70, 0·81	0·70	0·65, 0·75	0·67	0·62, 0·72	0·66	0·61, 0·71
SODIUMSALT	0·68	0·63, 0·73	0·66	0·61, 0·72	0·76	0·71, 0·82	0·71	0·66, 0·76	0·80	0·74, 0·85	0·79	0·74, 0·85

DRNA, dietary Na intake; URNA, urinary Na excretion.
* Based on least-squares means and lower and upper limits of CI generated by a linear mixed model for repeated measures for sex- and country-specific 24 h dietary recall or urinary biomarker.
† Unadjusted Na values.
‡ Adjusted for salt use based on a salt questionnaire.
§ Calculated as 24 h urinary Na divided by 0·9, with the assumption that 90 % of Na consumed is excreted in the urine.
‖ Ratio of Na intake estimated from the dietary recall to that estimated from the urinary biomarker (DRNA:URNA).

Table 3. Daily dietary sodium intake and urinary excretion measured in male and female subjects by BMI and country
(Geometric means* and 95 % confidence intervals)

	Belgium (*n* 123)				Norway (*n* 124)				Czech Republic (*n* 118)			
	Men		Women		Men		Women		Men		Women	
BMI category	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI
DRNA – SODIUMSALT†												
Normal weight (18·5–24·9 kg/m^2)	3314	2809, 3911	2594	2317, 2904	3781	3214, 4448	2413	2149, 2710	4988	4247, 5859	3523	3128, 3967
Overweight (25–29·9 kg/m^2)	3393	3023, 3808	2618	2195, 3122	3516	3152, 3922	2381	2044, 2773	4719	4093, 5441	3481	2993, 4050
Obese (≥ 30 kg/m^2)	2702	2199, 3319	2938	2256, 3827	3210	2341, 4401	2980	2302, 3857	4969	4190, 5894	3557	2692, 4701
URNA‡												
Normal weight (18·5–24·9 kg/m^2)	4121	3634, 4674	3749	3442, 4085	4393	3883, 4970	3287	3442, 4085	5913	5232, 6682	4036	3688, 4417
Overweight (25–29·9 kg/m^2)	4910	4498, 5360	4571	3998, 5226	4801	4418, 5217	3724	3998, 5226	6053	5433, 6744	4933	4397, 5534
Obese (≥ 30 kg/m^2)	5670	4838, 6645	4000	3273, 4889	5029	3957, 6391	3662	3273, 4889	6496	5706, 7396	5027	4068, 6213
Reporting accuracy§												
Normal weight (18·5–24·9 kg/m^2)	0·80	0·74, 0·87	0·69	0·64, 0·74	0·86	0·80, 0·93	0·73	0·68, 0·79	0·84	0·79, 0·90	0·87	0·82, 0·93
Overweight (25–29·9 kg/m^2)	0·69	0·64, 0·74	0·57	0·54, 0·61	0·73	0·68, 0·79	0·64	0·59, 0·69	0·78	0·72, 0·84	0·71	0·66, 0·75
Obese (≥ 30 kg/m^2)	0·48	0·44, 0·51	0·73	0·67, 0·81	0·64	0·59, 0·69	0·81	0·77, 0·86	0·76	0·72, 0·81	0·71	0·66, 0·76

DRNA, dietary Na intake; URNA, urinary Na excretion.
* Based on least-squares means and lower and upper limits of CI generated by a linear mixed model for repeated measures for sex-, country- and BMI-specific 24 h dietary recall or urinary biomarker.
† Adjusted for salt use based on a salt questionnaire.
‡ Calculated as 24 h urinary Na divided by 0·9, with the assumption that 90 % of Na consumed is excreted in the urine.
§ Ratio of Na intake estimated from the dietary recall to that estimated from the urinary biomarker (DRNA:URNA).

Table 4. Energy-adjusted urinary sodium excretion of the subjects by sex and country
(Mean values, standard deviations, median values and tertiles)

	Belgium		Norway		Czech Republic	
Na excretion (mg/MJ)*	Men (*n* 63)	Women (*n* 60)	Men (*n* 62)	Women (*n* 62)	Men (*n* 58)	Women (*n* 60)
Mean	484	515	457	456	597	602
SD	211	212	236	182	275	233
Median	432	476	410	411	538	569
First tertile cut-point	379	419	354	350	473	474
Second tertile cut-point	531	533	484	505	650	676

* Urinary Na excretion (mg/d) per MJ of dietary energy intake estimated from the EPIC-Soft 24 h dietary recall.

level and reporting accuracy by country and sex (data not shown).

Male and female subjects were classified into tertiles of urinary Na excretion (mg/d) per MJ of dietary energy intake. Arithmetic means, standard deviations, medians and tertiles are presented in Table 4. The median energy-adjusted Na excretion is higher for women than for men from Belgium (476 and 432 mg/MJ) and the Czech Republic (569 and 538 mg/MJ), respectively.

Na measurements and reporting accuracy for tertiles of energy-adjusted Na excretion are presented in Table 5. For the subjects among the lowest tertile of Na excretion per MJ, reporting accuracy was highest in all sex and countries. For subjects from the Czech Republic with low Na excretion per MJ, reporting accuracy of dietary Na intake was overestimated by 24–22 % for men and women, respectively.

Discussion

The present study was the first to investigate the reporting accuracy of dietary Na intake estimated by the EPIC-Soft 24-HDR method, which did not specifically ask for salt contents or use. Since 24 h urine collections were provided during the EFCOVAL study, analysis of urinary Na excretion provided a unique opportunity to assess the reporting accuracy of dietary Na intake. It is worth mentioning that at the time the EFCOVAL study was performed, calculation of dietary Na intake was not a priority; hence, procedures to link Na to foods and recipes were different across the participating countries. Nevertheless, although it was not the intention to assess dietary Na intake *a priori*, the available data are scientifically very interesting to explore and to allow further optimisation of the dietary intake assessment methods under study.

The reporting accuracy of dietary Na intake without salt adjustment (SODIUM scenario) tended to be lowest for Belgium and highest for the Czech Republic. This is probably because in the Belgian version of EPIC-Soft, no salt is added to composite meals. Only in recipes of soups, the Na present in stock cubes is taken into account. All other recipes and composite meals are treated as if no salt is added. In contrast, the EPIC-Soft version of the Czech Republic had salt included in standard recipes; therefore, dietary Na intake estimations were higher and closer to urinary Na excretion, resulting in higher reporting accuracy. For Norway, salt was only added to some standard recipes such as bread, meat sauce and fish cakes.

The salt adjustment procedure used information from the salt questionnaire to take into account the discretionary use of cooking or table salt (SODIUMSALT scenario). The salt adjustment procedure improved reporting accuracy among the subjects from both Belgium and the Czech Republic, while only 1 % increase in reporting accuracy was found for Norway. This can be explained because for Norwegian data, no salt addition factors were available for culinary treated food items. Since 89 and 77 % of Norwegian men and women, respectively, reported to use salt during cooking, a considerable part of the Norwegian sample should have had their Na intake being increased during the salt adjustment procedure. From the Norwegian data, it can also be concluded that the correction of Na intake based on the question of table salt use only minimally improved the reporting accuracy by 1 %. Therefore, in future analysis, the effect of higher standard amounts of Na added to reflect the discretionary use of table salt should be investigated. Nevertheless, it is believed that, in general, the contribution of household salt to total salt intake is limited. In a Danish study using a Li marker technique, Andersen *et al.*[9] found that the median contribution of household salt was 8–10 % of total salt intake.

Na intake was highly correlated with energy intake; however, because salt used during preparation of meals or consumption was not included in the EPIC-Soft 24-HDR and no salt facet was foreseen in the EFCOVAL versions of EPIC-Soft, a lower reporting accuracy for dietary Na intake might be expected. A previous study has indicated that extreme energy under-reporting is present in men and women (10 and 14 %, respectively)[30]. On average, men and women under-reported protein intake from two 24 h dietary recalls by 8 %[18]. When urinary Na excretion was adjusted for dietary energy intake, it was found that reporting accuracy was highest among the subjects from the lowest tertile, in all countries and both sexes. Therefore, it can be concluded that as Na density of a daily diet increases, the reporting accuracy of Na intake decreases. Na intake was overestimated by 24 and 22 % of Czech males and females among the lowest tertile of urinary Na per MJ of energy intake. When the SODIUM scenario was used, reporting accuracy was 1·10 and 0·98 for men and women, respectively (data not shown). Further analysis of salt addition factors for culinary treated foods revealed that these factors were considerably higher in the Czech Republic compared with those used in Belgium. It is assumed that these higher addition factors are responsible for the

Table 5. Daily dietary sodium intake and urinary excretion measured in male and female subjects by tertiles (T) of energy-adjusted sodium intake and country (Geometric means* and 95 % confidence intervals)

	Belgium (*n* 123)				Norway (*n* 124)				Czech Republic (*n* 118)			
	Men		Women		Men		Women		Men		Women	
Tertile URNA/MJ†	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI	Geometric mean	95 % CI
DRNA – SODIUMSALT‡												
T1	3268	2896, 3687	2811	2441, 3237	3846	3422, 4324	2686	2389, 3020	6674	5610, 7939	3843	3235, 4564
T2	3379	2945, 3875	2574	2285, 2901	3558	3115, 4063	2407	2081, 2784	4513	3962, 5141	3830	3333, 4401
T3	3067	2677, 3514	2558	2203, 2972	3077	2612, 3625	2160	1859, 2510	4525	4007, 5109	3229	2887, 3612
URNA§												
T1	3850	3573, 4150	3077	2822, 3355	3720	3460, 4000	2854	2653, 3070	5375	4835, 5976	3150	2836, 3500
T2	4975	4573, 5413	3969	3686, 4274	5091	4690, 5526	3670	3354, 4015	5527	5100, 5989	4071	3739, 4433
T3	6268	5766, 6813	5267	4804, 5774	6611	5975, 7314	4578	4174, 5022	7082	6568, 7636	5270	4914, 5651
Reporting accuracy‖												
T1	0·85	0·78, 0·92	0·91	0·85, 0·98	1·03	0·96, 1·11	0·94	0·88, 1·00	1·24	1·18, 1·31	1·22	1·15, 1·30
T2	0·68	0·63, 0·73	0·65	0·61, 0·69	0·70	0·66, 0·74	0·66	0·62, 0·69	0·82	0·77, 0·87	0·94	0·88, 1·00
T3	0·49	0·46, 0·52	0·49	0·46, 0·52	0·47	0·44, 0·50	0·47	0·44, 0·50	0·64	0·60, 0·68	0·61	0·58, 0·65

DRNA, dietary Na intake; URNA, urinary Na excretion.
* Based on least-squares means and lower and upper limits of CI generated by a linear mixed model for repeated measures for sex-, country- and tertile of energy-adjusted Na intake-specific 24 h dietary recall or urinary biomarker.
† Tertiles of urinary Na excretion (mg/d) per MJ of dietary energy intake.
‡ Adjusted for salt use based on a salt questionnaire.
§ Calculated as 24 h urinary Na divided by 0·9, with the assumption that 90 % of Na consumed is excreted in the urine.
‖ Ratio of Na intake estimated from the dietary recall to that estimated from the urinary biomarker (DRNA:URNA).

overestimation of Na intake among the subjects in the lowest tertile of urinary Na excretion per MJ of energy intake.

In a study of 465 American subjects aged 30–69 years, the overall reporting accuracy of dietary Na intake using the automated multiple-pass method compared with 24 h urinary excretion was 0·93 for men and 0·90 for women[28]. A larger underestimation of Na intake was found with increasing BMI category among men and women. In a study of 353 young, lean (mean BMI 21·1 kg/m^2) female Japanese dietetic students, over-reporting of Na decreased with increasing BMI quintile category[31]. The present study shows that for Belgian and Norwegian women, dietary Na intake was highest for obese subjects compared with normal-weight and overweight subjects; while in contrast to all the other obese subjects, their urinary Na excretion was lower than overweight subjects.

The participants of the present study were highly motivated; only two subjects failed to collect their second urine sample. PABA was used to verify the completeness of urine collections. Based on the recovery of PABA, only 1 % was treated as incomplete (PABA recovery below 50 %) and 8 % of collections were proportionally adjusted to 93 % of PABA recovery (50 % < PABA recovery < 85 %). When proportionally adjusted collections were excluded from the analysis, overall reporting accuracy did not differ from that reported.

The correction factor used for estimating Na intake from 24 h urine collections should be taken into account when interpreting the results of the present study. Since the field-work of the urine collections was performed during winter, a correction factor of 90 % was chosen. Holbrook *et al.*[12] showed that seasonal variation in urinary Na excretion is present, probably associated with sweating. In the study performed by Rhodes *et al.*[28], a correction factor of 86 % was used, while other studies used 95 %[32]. The use of other correction factors or no correction factor would influence the magnitude of misreporting.

It is challenging to assess dietary Na intake in free-living individuals due to its high day-to-day variation, its diversity in sources (naturally present, added by the industry or discretionary use of salt at home) and changing salt concentrations of industrial foods over time. Indeed, Na reduction intervention plans have led to considerable commitment of the food industry to lower the Na content of processed foods. Consequently, the large diversity of foods available on the food market and the change in Na content due to the reformulation of foods require a continuous updating of food composition databases.

Conclusions

The present study shows considerable underestimation of dietary Na intake at both the population and subgroup levels when using the EPIC-Soft 24-HDR versions that do not include any specific questions regarding salt content/use. The salt adjustment procedure presented herein increased the reporting accuracy, but not to satisfying levels. Given that during the EPIC-Soft-guided 24-HDR, discretionary use of table or cooking salt was not assessed and no salt facet was foreseen, the low reporting accuracy observed is not surprising.

Reporting accuracy tended to be highest in the Czech Republic with considerable overestimation of Na intake among the subjects with low urinary Na excretion per MJ of energy intake. Data from Belgium showed the lowest reporting accuracy. Therefore, inclusion of salt use in composite meals and recipes should be considered in future. Finally, to accurately estimate the population dietary Na intake, using the EPIC-Soft 24-HDR method, future development of facets and descriptors related to discretionary use of salt is necessary.

Acknowledgements

The authors thank the EFCOVAL partners for their useful advice and the respondents for their participation. The EFCOVAL partners are Ghent University (DPH), Belgium; Academy of Medical Sciences (AMZH), Croatia; National Institute of Public Health (NIPH), Czech Republic; National Food Institute, Technical University of Denmark (DTU), Denmark; French Food Safety Authority (AFSSA), France; National Institute for Agricultural Research (INRA), France; German Institute of Human Nutrition (DIfE), Germany; National Research Institute for Food and Nutrition (INRAN), Italy; Wageningen University (WU), The Netherlands; National Institute for Public Health and the Environment (RIVM), The Netherlands; University of Oslo, Norway; Basque Foundation for Health Innovation and Research (BIOEF), Spain; Prima Informatics Limited (Primainfo), UK; and International Agency for Research on Cancer (IARC, WHO). The present study reflects only the authors' views and the European Community is not liable for any use that may be made of the information contained therein. The authors thank Roos Colman for her advice regarding the statistical analysis. They also acknowledge Ziggy Buyle and Hannes Timmerman for their work regarding the Belgian salt addition factors.

The EFCOVAL Project was supported by the community funding under the Sixth Framework Program (FOOD-CT-2006-022895). The present study was supported by the research fund of University College Ghent (to W. D. K.). Both funders had no role in the design and analysis of the study or in the writing of this article.

The authors' contributions are as follows: W. D. K. carried out the data analyses and wrote the paper; E. d. B., P. v. V. and N. S. designed and coordinated the overall EFCOVAL Project; A. G., J. R., I. H., S. D. H. and L. F. A. were local coordinators; W. D. K., M. D., I. T. L. L., M. D. M., I. R. and S. P. C. were involved in the fieldwork. All authors contributed to the interpretation of the results, commented on the paper and approved the final version.

None of the authors has any conflict of interest to declare.

References

1. WHO (2012) *Guideline: Sodium Intake for Adults and Children*. Geneva: World Health Organization.
2. Graudal NA, Hubeck-Graudal T & Jurgens G (2011) Effects of low sodium diet versus high sodium diet on blood pressure, renin, aldosterone, catecholamines, cholesterol, and triglyceride. *The Cochrane Database of Systematic Reviews 2011,* issue 11, CD004022.
3. Dietary Guidelines Advisory Committee (2010) *Adults and Sodium: What is the Relationship between Sodium and Blood Pressure in Adults Aged 19 Years and Older?* Washington, DC: Department of Health and Human Services and Department of Agriculture.
4. Dickinson HO, Mason JM, Nicolson DJ, *et al.* (2006) Lifestyle interventions to reduce raised blood pressure: a systematic review of randomized controlled trials. *J Hypertens* **24**, 215–233.
5. He FJ & MacGregor GA (2004) Effect of longer-term modest salt reduction on blood pressure. *The Cochrane Database of Systematic Reviews 2004,* issue 3, CD004937.
6. Taylor RS, Ashton KE, Moxham T, *et al.* (2011) Reduced dietary salt for the prevention of cardiovascular disease. *The Cochrane Database of Systematic Reviews 2011,* issue 7, CD009217.
7. Strazzullo P, D'Elia L, Kandala NB, *et al.* (2009) Salt intake, stroke, and cardiovascular disease: meta-analysis of prospective studies. *BMJ (Clinical Research Ed)* **339**, b4567.
8. Anderson CA, Appel LJ, Okuda N, *et al.* (2010) Dietary sources of sodium in China, Japan, the United Kingdom, and the United States, women and men aged 40 to 59 years: the INTERMAP study. *J Am Diet Assoc* **110**, 736–745.
9. Andersen L, Rasmussen LB, Larsen EH, *et al.* (2009) Intake of household salt in a Danish population. *Eur J Clin Nutr* **63**, 598–604.
10. Brown IJ, Tzoulaki I, Candeias V, *et al.* (2009) Salt intakes around the world: implications for public health. *Int J Epidemiol* **38**, 791–813.
11. Ribic CH, Zakotnik JM, Vertnik L, *et al.* (2010) Salt intake of the Slovene population assessed by 24 h urinary sodium excretion. *Public Health Nutr* **13**, 1803–1809.
12. Holbrook JT, Patterson KY, Bodner JE, *et al.* (1984) Sodium and potassium intake and balance in adults consuming self-selected diets. *Am J Clin Nutr* **40**, 786–793.
13. Bingham S & Cummings JH (1983) The use of 4-aminobenzoic acid as a marker to validate the completeness of 24 h urine collections in man. *Clin Sci (Lond)* **64**, 629–635.
14. Joossens JV & Geboers J (1984) Monitoring salt intake of the population: methodological considerations. In *Surveillance of the Dietary Habits of the Population with Regard to Cardiovascular Diseases, EURONUT Report 2*, pp. 61–73 [GG De Backer, HT Pedoe and P Ducimetiere, editors]. Wageningen: Department of Human Nutrition, Agricultural University.
15. De Keyzer W, Huybrechts I, Dekkers AL, *et al.* (2012) Predicting urinary creatinine excretion and its usefulness to identify incomplete 24 h urine collections. *Br J Nutr* **108**, 1118–1125.
16. Brussaard JH, Lowik MR, Steingrimsdottir L, *et al.* (2002) A European food consumption survey method – conclusions and recommendations. *Eur J Clin Nutr* **56**, Suppl. 2, S89–S94.
17. Huybrechts I, Geelen A, de Vries JH, *et al.* (2011) Respondents' evaluation of the 24-h dietary recall method (EPIC-Soft) in the EFCOVAL Project. *Eur J Clin Nutr* **65**, S29–S37.
18. Crispim SP, Geelen A, de Vries JH, *et al.* (2012) Bias in protein and potassium intake collected with 24-h recalls (EPIC-Soft) is rather comparable across European populations. *Eur J Nutr* **51**, 997–1010.
19. de Boer EJ, Slimani N, van 't Veer P, *et al.* (2011) Rationale and methods of the European Food Consumption Validation (EFCOVAL) Project. *Eur J Clin Nutr* **65**, Suppl. 1, S1–S4.
20. Slimani N, Deharveng G, Charrondiere RU, *et al.* (1999) Structure of the standardized computerized 24-h diet recall interview used as reference method in the 22 centers participating in the EPIC project. European Prospective

Investigation into Cancer and Nutrition. *Comput Methods Programs Biomed* **58**, 251–266.
21. Slimani N, Ferrari P, Ocke M, *et al.* (2000) Standardization of the 24-hour diet recall calibration method used in the European Prospective Investigation into Cancer and Nutrition (EPIC): general concepts and preliminary results. *Eur J Clin Nutr* **54**, 900–917.
22. NUBEL (2004) *Belgian Food Composition Table*, 4th ed. Brussels: Ministry of Public Health (in Dutch).
23. NEVO-TABEL (2006) *Nederlandse Voedings Middelen Tabel (Dutch Food Composition Tables)*. Den Haag: Rijksinstituut voor Volksgezondheid en Milieu.
24. MVT-06 (2006) The Norwegian Food Composition Table. Oslo: Norwegian Food Safety Authority. http://www.matportalen.no/matvaretabellen
25. Food Research Institute (1997–2002) *Pozivatinove tabulky (Food Composition Tables for Slovakia)*. Bratislava: Food Research Institute.
26. USDA (2011) National Nutrient Database for Standard Reference, Release 24 – Nutrient Data Laboratory Home Page. http://www.ars.usda.gov/ba/bhnrc/ndl
27. Johansson G, Bingham S & Vahter M (1999) A method to compensate for incomplete 24-hour urine collections in nutritional epidemiology studies. *Public Health Nutr* **2**, 587–591.
28. Rhodes DG, Murayi T, Clemens JC, *et al.* (2013) The USDA Automated Multiple-Pass Method accurately assesses population sodium intakes. *Am J Clin Nutr* **97**, 958–964.
29. Julious SA (2004) Sample sizes for clinical trials with normal data. *Stat Med* **23**, 1921–1986.
30. Ferrari P, Slimani N, Ciampi A, *et al.* (2002) Evaluation of under- and overreporting of energy intake in the 24-hour diet recalls in the European Prospective Investigation into Cancer and Nutrition (EPIC). *Public Health Nutr* **5**, 1329–1345.
31. Murakami K, Sasaki S, Takahashi Y, *et al.* (2008) Misreporting of dietary energy, protein, potassium and sodium in relation to body mass index in young Japanese women. *Eur J Clin Nutr* **62**, 111–118.
32. Vandevijvere S, De Keyzer W, Chapelle JP, *et al.* (2010) Estimate of total salt intake in two regions of Belgium through analysis of sodium in 24-h urine samples. *Eur J Clin Nutr* **64**, 1260–1265.

British Journal of Nutrition