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ORIGINAL CONTRIBUTION

Current daily salt intake in Germany: biomarker-based analysis of the representative DEGS study

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Abstract

Purpose A high dietary salt intake is a serious risk factor for the development of hypertension. Daily salt intake in most of the European countries substantially exceeds the current recommendations of salt intake. For Germany, so far, no valid biomarker-based data on current daily salt intake are available.

Methods Data basis for this biomarker-based estimation of salt intake in the German population was the representative DEGS Study (German Health Interview and Examination Survey for Adults) conducted 2008–2011 in 18–79 old adults living in Germany. Daily salt intake was estimated from 6,962 sodium and creatinine measurements in spot urine samples.

Results Median estimated daily salt intake of the 18–79 olds was 10.0 g in men and 8.4 g in women. More than 75 % of men and about 70 % of women exceeded the current recommendation of a maximum salt intake of 6 g/day. Fifty percentage of men and more than 35 % of the women had a daily salt intake >10 g.

Conclusion Daily salt intake of the German population considerably exceeds the current recommendation to eat no more than 6 g salt per day. A general reduction of salt content in processed foods—which are currently the main source of salt intake—offers a promising and cost-effective potential for the improvement of all salt intake-dependent health outcomes in the population.

Keywords Salt intake · Germany · DEGS Study · Urinary sodium excretion

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Background

Meanwhile, it is well established that a high salt intake is one important risk factor for increased blood pressure and the development of hypertension [1, 2]. Even if the epidemiological evidence is incomplete with regard to the relevance of salt intake for CVD morbidity and mortality and therefore the degree of benefit of a salt reduction is still debated [3, 4], it is widely accepted that a general reduction of salt intake in a population will beneficially affect overall health [1, 4–6].

The WHO recommends a population salt intake level of less than 5 g per person per day for the prevention of cardiovascular diseases [7]; the German-speaking nutrition societies (D-A-CH) recommend to eat no more than 6 g salt per day [8]. For specific risk groups (older age, hypertensives, African-Americans), the Dietary Guidelines for Americans even recommend to reduce their salt intake to less than 3.8 g/day [9]. Current salt intake in most of the European countries ranges between 8 and 12 g per day, therefore at an amount that clearly exceeds the recommended salt intake levels [6].

So far, for Germany, valid data on daily salt intake are missing. The only available current data were collected in the second National Food Consumption Survey (NVS II, 2005–2007) [10], however, only on the basis of diet history interviews. Such dietary assessment methods generally can only give a crude picture of actual salt intake as the amount of salt added at the table cannot be quantified, and especially for processed foods (e.g., bread, ready-to-eat-products), mostly insufficient information on salt content is available. This may be one reason why according to the NVS II data, Germany appeared to be one of the countries with the lowest salt intake throughout Europe [6].

The "gold standard" to determine salt intake is the measurement of urinary sodium excretion for 24 h [11], which however is not feasible in large representative studies. With the collection of about 7000 spot urine samples in the German Health Interview and Examination Survey for Adults (DEGS Study, 2008–2011), representative for the German adult population, the so far lacking data basis was created to estimate current German salt intake by measurements of urinary sodium excretion.

Methods

DEGS study

The German Health Interview and Examination Survey for Adults ("Studie zur Gesundheit Erwachsener in Deutschland," DEGS) is part of the health monitoring system at the Robert Koch Institute (RKI), Berlin. The concept and design of DEGS are described in detail elsewhere [12–14].

The first wave (DEGS1) was conducted from 2008 to 2011 and comprised interviews and physical examinations and tests. The target population comprised the resident population of Germany aged 18–79 years. DEGS1 has a mixed design which permits both cross-sectional and longitudinal analyses. For this purpose, a random sample from local population registries was drawn to complete the participants of the German National Health Interview and Examination Survey 1998 (GNHIES98), who re-participated. A total of 8,152 persons participated, including 4,193 first-time participants (response rate 42 %) and 3,959 revisiting participants of GNHIES98 (response rate 62 %) [15].

The present analyses are based on data from DEGS1 participants for whom measurements of urinary sodium and creatinine in spot urine samples were available ($n = 6{,}962$). The DEGS study was approved by the Ethics Committee of Charité, University Medicine, Berlin, Germany.

Urinary sodium concentration was determined by ion-sensitive electrode (ISE; indirect method), on the Architect platform CI 8,200, Abbott, USA. Urinary creatinine concentration was measured using a colorimetric method (picrate), also on the Architect CI 8,200, Abbott, USA.

Estimation of 24-h salt intake from renal sodium excretion in spot urine samples

Measured analyte concentrations in spot urine samples (e.g., sodium concentration) can vary considerably by hydration status (diluted or concentrated urine samples). To correct for these potential influences of urine volume, frequently analyte to creatinine ratios are calculated as creatinine is excreted at a relatively constant rate throughout the day—primarily dependent on sex and age [16, 17]. Furthermore, 24-h analyte excretion can be estimated by correcting the variable of interest (analyte/creatinine ratio) by 24-h creatinine excretion reference values [16]. Accordingly, to estimate 24-h sodium excretion in the present DEGS Study, urinary sodium to creatinine ratios were corrected for age- and sex-specific 24-h creatinine excretion reference values.

$$\begin{aligned} &\text{Estimated daily sodium intake } (\mathrm{g/d}) \\ &= \frac{\text{Na - Concentration } [\mathrm{g}] \cdot [1/\mathrm{L}]}{\text{Creatinine - Concentration } [\mathrm{mmol}] \cdot [1/\mathrm{L}]} \\ &\quad \times \frac{\text{Creatinine - Reference } [\mathrm{mmol}]}{[24\text{ - h}]} \end{aligned}$$

Example (DEGS men)

11.3 [mmol/mmol] sodium/creatinine ratio × 15.1 [mmol/24-h] average creatinine-reference value (men) × 0.023 [g/mmol] × 2.54 = 10 [g/d] salt intake. (1 mmol Na = 0.023 g Na; 1 g Na = 2.54 g NaCl).

Present data basis for adult 24-h creatinine excretion reference values was the—so far unpublished—24-h creatinine excretion data from the German VERA Study [18, 19]. The VERA Study (Verbundstudie Ernährungserhebung und Risikofaktoren-Analytik) was a representative sub-sample taken randomly from the first National Food Consumption Survey (NVS I) of the Federal Republic of Germany (1986 and 1988), comprising 2006 subjects, aged 18–88, of whom each subject collected one 24-h urine sample. All completely collected 24-h urine samples of the VERA Study were analyzed directly after they have been collected.

In 269 subjects (of 2006 in total), the urine collection time was not in the range of 1,200–1,560 min. In 118 subjects, 24-h urine creatinine was below 0.1 mmol/kg per day [16], and in two subjects, 24-h urine volume was below 300 ml. All these urines have been excluded for the generation of 24-h creatinine reference values. The 24-h creatinine reference values were available for 18–79-year-old men and women in 10-year age groups (18–29 year, 30–39 year, 40–49 year, etc.). Mean 24-h creatinine excretion (18–79 year) was 15.1 mmol/d in men and 10.8 mmol/d in women.

Daily renal salt (NaCl) excretion in DEGS was calculated from estimated 24-h urinary sodium excretion

Table 1 Analyzed sodium concentration in DEGS spot urine samples and derived estimates of salt intake, stratified by sex and age groups (median, 25th and 75th percentile)

Age	*n*	Urinary sodium (mmol/l)	Sodium/creatinine ratio (mmol/mmol)	Estimated salt intake (g/day)*	
				Median (P25; P75)	95 % CI[a,b]
Women					
18–29	534	80.2 (43.3; 139.5)	11.4 (7.6; 16.3)	7.4 (4.9; 10.6)	6.8–8.0
30–39	420	57.2 (32.2; 104.5)	12.2 (8.4; 17.4)	8.2 (5.5; 11.8)	7.6–9.0
40–49	681	51.0 (30.9; 93.3)	13.1 (8.4. 18.7)	9.1 (5.9; 13.0)	8.3–9.7
50–59	744	52.7 (30.7; 92.7)	14.7 (8.7; 21.5)	9.2 (5.5; 13.5)	8.6–9.8
60–69	714	60.2 (37.0; 93.8)	14.5 (8.5; 20.6)	8.6 (5.0; 12.2)	7.9–9.0
70–79	529	60.3 (39.4; 92.5)	14.3 (9.5; 23.2)	7.9 (5.2; 12.8)	7.5–8.5
♀	**3,622**	**59.0 (35.1; 104.9)**	**13.3 (8.3; 19.8)**	**8.4 (5.3; 12.5)**	**8.1–8.7**
Men					
18–29	507	106.2 (56.7; 162.7)	10.5 (7.1; 16.6)	9.4 (6.5; 15.1)	8.7–10.2
30–39	403	92.1 (48.4; 146.3)	11.0 (7.3; 15.8)	10.6 (7.1; 15.2)	9.6–11.6
40–49	586	99.8 (52.1; 143.3)	10.9 (7.2; 15.1)	9.6 (6.3; 13.3)	8.7–10.2
50–59	630	101.2 (57.0; 153.0)	11.6 (7.3; 14.2)	10.4 (6.6; 15.0)	9.8–11.1
60–69	671	96.6 (58.7; 135.0)	12.3 (7.9; 17.1)	10.4 (6.7; 14.5)	9.7–11.4
70–79	543	94.0 (59.3; 132.3)	12.3 (8.6; 17.7)	9.8 (6.8; 14.1)	9.3–10.5
♂	**3,340**	**99.2 (54.8; 145.4)**	**11.3 (7.5; 16.4)**	**10.0 (6.7; 14.5)**	**9.7–10.4**

* Salt intake was estimated from the sodium/creatinine ratio by multiplication with age- and sex-stratified creatinine excretion reference values. These were derived from the VERA Study [16, 17] and will be published separately. For an example of 24-h salt intake calculation, see method section

[a] Significant differences in median salt intake over all age groups in women ($P < 0.0001$) and men ($P = 0.05$; Kruskal–Wallis Test)

[b] Significant differences in median salt intake between the sexes ($P < 0.0001$; Wilcoxon rank-sum test)

Bold values represent the total number of examined women or men along with the corresponding sex-stratified overallmedian values for urinary sodium, sodium/creatinine and estimated salt intake.

(393 mg sodium = 1 g salt), and renal salt excretion was assumed to equal salt intake.

All analyses were performed using SAS (version 9.2, SAS Institute, 107 Cary, NC, USA). Results are presented as medians with 25th and 75th percentiles. All results shown were calculated using a weighting factor which corrects deviations in the sample from the population structure (as of 31 Dec 2010) with regard to age, sex, region and nationality, as well as community type and education [20]. Differences between age groups were tested by Kruskal–Wallis analysis of variance, and sex differences were tested by Wilcoxon rank-sum test. Statistical significance was defined as $P < 0.05$.

Results

In Table 1, median urinary sodium concentrations are presented along with the estimates of daily salt intake resulting from the urinary sodium/creatinine ratios of the DEGS study sample. Figure 1 visualizes the distribution of salt intake in the different sex and age groups. Median estimated daily salt intake of the 18–79-year-old DEGS participants was 10.0 g in men and 8.4 g in women (significantly different, $P < 0.0001$). Women had the highest median salt intakes in the age range of 40–59 years, and men had the highest intakes in the age range of 50–69 years (P values for age-group differences: $P < 0.0001$ in women, $P = 0.05$ in men; Table 1).

Eighty percentage of the male and 70 % of the female DEGS population exceeded the nationally recommended maximum salt intake of 6 g/day; the WHO recommendation of 5 g/day was in the younger male age groups exceeded by up to 87 %. The upper level of 10 g salt intake per day was still exceeded by 50 % of men and 39 % of women (Table 2).

The comparison of the biomarker-based estimated median salt intake in DEGS with salt intakes found in the second German National Consumption Survey (NVS II, diet history interviews) reveals reliably higher intakes within DEGS (about 2 g/day) (Fig. 2). In Table 3, a comparison of the current salt intakes in adults in Germany with other European countries is provided.

Discussion

With a current median daily salt intake of 10 g in men and 8 g in women, the German population considerably exceeds the national and international recommendations

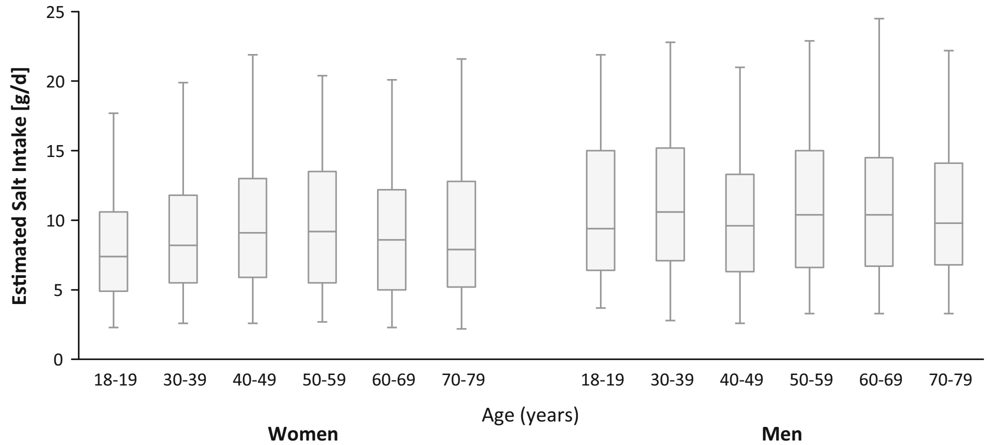

Fig. 1 Distribution of salt intake in the DEGS population. The *boxplots* represent the 5th, 25th, 50th, 75th and 95th percentile of salt intake estimates

Table 2 Percentage of DEGS participants with an estimated daily salt intake of >5 g, >6 g, >10 g, and >15 g

Age	Women				Men			
	>5 g/day	>6 g/day	>10 g/day	>15 g/day	>5 g/day	>6 g/day	>10 g/day	>15 g/day
18–29	73.9	63.0	29.7	10.7	87.0	78.5	47.2	25.0
30–39	78.4	68.7	34.6	13.5	87.0	81.9	54.6	26.9
40–49	80.3	74.1	43.8	19.9	84.5	77.7	45.7	17.8
50–59	77.8	72.2	45.0	16.1	86.2	80.8	53.4	25.1
60–69	75.2	69.1	37.1	14.0	85.6	79.2	52.0	23.9
70–79	77.0	68.6	39.9	15.3	86.9	79.5	48.9	22.1
Total	77.2	69.5	38.6	15.1	86.1	79.5	50.0	23.2

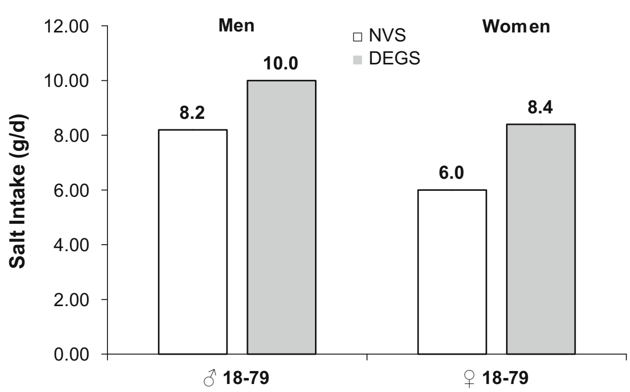

Fig. 2 Comparison of the biomarker-based estimation of median daily salt intake in DEGS (2008–2011) with the results of the diet history interviews from the NVS II (2005–2007) [10]

for salt intake. 70–80 % of the representative sample of the German population lay above 6 g salt intake per day, the recommended maximum intake level in Germany that is proposed to be non-disadvantageous.

The observation that salt intake in men was significantly higher than in women can be explained by the physiologically higher total daily energy intake of men. In accordance herewith, men in NVS II also had an about 2 g higher salt intake per day than women, however, on a lower median level (8.2 vs. 6 g/day). Based on the latter, not yet biomarker-based NVS data, Germany so far was a lower

Table 3 European comparison of current salt intake estimates for adults, assessed by urinary sodium excretion (adapted from [6])

Country	Salt intake (g/day)			
	Women	Men	Year	References
Germany	8.4	10.0	2008–2011	
Belgium (Walloon/ Flanders)	8.6/9.9	11.5/ 11.8	2009	[29]
England	6.8	9.3	2011	[27]
Hungary	12.0	17.2	2009/10	[23]
Italy	8.3	10.8	2008	[22]
Netherlands	7.5	9.9	2007–2010	[28]
Portugal	12.3	12.3	2006	[25]
Slovenia	11.0	14.3	2007	[26]
Spain	8.4	11.5	2009	[24]
Switzerland	7.8	10.6	2010/11	[21]

salt intake region in comparison with other European countries [6]. However, as already described previously, salt intake estimates, derived from dietary intake data, lead to an underestimation of actual salt intake of about 20–40 % [11]. With the current biomarker-based salt intake estimation, it is now shown that actual salt intake in Germany is remarkably higher and rather lies in the same range of intake as most other European countries (with mean salt intake, measured by urinary sodium, of 8–12 g/day) (Table 3). Interestingly, the lowest values (9.3 and 6.8 g/day, respectively) have been observed in England after salt reduction strategies already have been implemented [27]. Salt intake decreased about 1.4 g/day from 2000/01 to 2011 (from 11.0 to 9.3 g per day for men and from 8.1 to 6.8 g per day for women).

In the DEGS Study, the lowest salt intake values have been observed in the youngest age groups (applies for both sexes). Actually, these low estimates are quite reasonable as in this age group (19–29 year) physical activity can be expected to be the highest. Physical activity leads to a higher salt loss through sweat and therefore to a lower sodium excretion through urine. However, as already stated above, salt that is lost through sweat has no impact on pathophysiologically relevant processes; therefore, measured urinary sodium excretion particularly reflects the salt intake component that is systemically and metabolically active. Interestingly, in the NVS II (the most current German National Consumption Survey) for women in the youngest age group (19–24) [10], also the lowest salt intake has been observed, probably pointing at a preference for a more healthy diet (i.e., diets low in salt) in women in this age group.

Unfortunately, so far no data on the main sources of salt in the diet of DEGS participants have been investigated. This would be an important information for future implementation of effective salt reduction strategies. However, from the most current representative survey on dietary intakes in Germany—the NVS II—it can be concluded that the highest contribution to sodium/salt intake stems from the food groups bread, meat and sausages, and milk products [10].

In the present investigation, salt intake was estimated by measurements of urinary sodium excretion, which so far has been considered—at least with respect to 24-h collections—as gold standard for the estimation of salt intake. However, just recently, the traditional opinion that in a steady state, salt intake matches salt excretion has been questioned by the group of Titze et al. [30, 31]. They found that salt can also be stored largely in the skin interstitium, and therefore, extracellular sodium homeostasis is not exclusively a “renal affair.” In a Mars flight simulation, they found that with a constant salt intake, salt excretion is circaseptian (7 days). The latter questions the idea that single 24-h urines—the current gold standard—are a valid indicator of salt intake in humans. However, despite this critic on the biomarker urinary sodium excretion—that is worth to be pursued—in large-scale epidemiological studies (like the present one) which are not aiming at characterizing salt intake on an individual level, group mean estimation is very probably not affected. The accuracy of the present data is further underlined by the remarkably plausible agreement with the results from the dietary assessment of the NVS.

One limitation of the present analysis with regard to the estimation of sodium intake from urine measurements is the collection of only spot urines instead of 24-h urines since sodium is not constantly excreted over a 24-h period [32]. Therefore, salt intake estimates may be biased dependent on the time of the collection. However, due to the large sample size, in DEGS 24-h urine collections would not have been feasible. Urine collection time has not been fixed in the study protocol of the DEGS study and therefore was distributed over the whole day: about 40 % of the spot urines were collected in the morning (up to noon) and 60 % in the afternoon (later than noon). With regard to this well-balanced manner of the time of spot urine collection in combination with the large sample size, it can be assumed that in the median, the circadian fluctuations of sodium will level out. This is further supported by a study from Cogswell et al. in which group mean 24-h sodium excretion was estimated from spot urine samples with a deviation of ±200 mg [33], equaling merely to 0.5 g salt—a deviation that is acceptable for the estimation of “true” salt intake. Furthermore, in this study, it was stated that “…in general, mean predicted 24-h sodium excretion based on specimens collected in the afternoon and evening, compared with morning or overnight, was a better approximation of mean 24-h sodium excretion” [33].

Obviously, with the measurement of urinary sodium excretion, ingested sodium that already has been excreted through sweat, cannot be captured. In the normal range of sweat production (i.e., without extreme physical strains), sodium loss through sweat is about 400 mg, equaling about 1 g salt (NaCl) [34]. Therefore, in average conditions, the measurement of urinary sodium excretion may underestimate real sodium intake in this range. At the same time, it has to be considered that—independent from sodium intake stemming from NaCl (salt)—every day, also so-called inherent sodium (i.e., sodium naturally incorporated in foods) is ingested [35]. This sodium appears as sodium bicarbonate (sodium sulfate or sodium phosphate) or in organic compounds which has different physiological effects than added NaCl. Inherent sodium also appears at an amount of about 400–500 mg and is excreted renally. Therefore, it can be expected that ingestion of inherent sodium and sodium loss through sweat more or less compensate each other so that in sum, the urinary sodium is a very good reflection of actual sodium (salt) intake. Apart from this, it absolutely has to be kept in mind that the amount of NaCl intake that is lost through sweat has no (negative) impact on physiological processes and therefore has to be differently judged. In fact, the biomarker urinary sodium excretion may provide a much better estimation/approximation of metabolically active salt intake.

Up to now, no specific political strategy has been established to approach a certain salt reduction in Germany. As in industrialized countries nowadays up to 80 % of daily salt intake derives from processed foods, one of the most effective salt reduction measures will be a reduction in that food category. For Germany, bread and/or meat products could be ideal target foods due to their relatively high consumption and their important role for salt intake. While food industry is in general an important player in affecting salt intake of the population, experience from other countries has shown that measures which are implemented by the government and accordingly set standards and targets for food industry are the most effective [36].

In conclusion, also for Germany, a politically accompanied salt reduction seems to be a promising approach to contribute to a general health improvement of the population. The present data, representative for the current German adult population, represent a clear appeal to policy makers to deliberate on next steps and possible legislative measures.

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Conflict of interest The authors have nothing to declare.

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