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ORIGINAL ARTICLE

Twelve-year trends and correlates of dietary salt intakes for the general adult population of Geneva, Switzerland

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Background/Objectives: Investigate dietary salt intake trends by gender, and their associations with risk factors for cardiovascular diseases in Geneva, Switzerland.
Subjects/Methods: Continuous surveillance of the Geneva general adult (35–74 years) population for 12 years (1993–2004) using a validated, semi-quantitative food frequency questionnaire (FFQ) in random, cross-sectional, representative samples (6688 men, 6647 women). Dietary salt intake assessment by FFQ excluded discretionary salt, but was calibrated on total salt intake using an independent validation substudy of 100 volunteers who additionally provided 24-h urine collections.
Results: Quartiles (mean) of calibrated dietary salt intake (g per day) were 9.9, 10.5, 11.2 (10.6) in men, and 7.0, 7.8, 8.9 (8.1) in women and were above current recommendations. Quartiles (mean) of salt density (g MJ^{-1}) were 0.99, 1.16, 1.39 (1.23) in men, and 0.98, 1.12, 1.30 (1.17) in women. Both measures were stable during the 12-year surveillance period, regardless of hypertension treatment. Salt-density differences between cardiovascular disease risk factor subgroups were moderate. Salt density increased with age and body mass index. The main dietary non-discretionary salt food sources (men/women: 47/48%) were breads (17/17%), cheeses (11/10%), meat and meat products (8/7%), soups (6/9%) and ready-to-eat foods (5/5%).
Conclusions: Salt intakes from all sources for the Geneva, and perhaps the Swiss adult population are above current recommendations. The quantitative and qualitative data provided in this paper could be used to develop and implement strategies for salt-intake reduction in Switzerland.
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Keywords: diet; food sources; food frequency questionnaire; salt; sodium; Switzerland

Introduction

There is growing interest in the association of dietary habits, especially regarding sodium, potassium and calcium intakes, with the elevation of blood pressure in general populations (Geleijnse *et al.*, 2005).

Specific surveillance programs of salt intake, such as the former North-Karelia Salt Project (Pietinen *et al.*, 1996), continued as the FINRISK/FINDIET Projects (Männistö *et al.*, 2003; Laatikainen *et al.*, 2006; Reinivuo *et al.*, 2006), are relatively rare. Many countries with no national dietary survey program, including Switzerland, rely on food supply and utilization data (Food Balance Sheets), which refer to average food available for consumption, but not to individual food intake (Joint WHO/FAO Expert Consultation, 2003). We were able to capitalize on a regional dietary surveillance program conducted continuously from 1993 through 2004 in Geneva to analyze dietary salt intakes from food stuffs, characterizing salt intake for both genders

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by food groups and diverse socio- and health-behavioral factors.

Methods

Twelve-year surveillance and study subjects
A community-based surveillance project designed to monitor chronic disease risk factors in the Swiss canton of Geneva, with a population of about 438 500 primarily French-speaking inhabitants, was conducted from 1993 through 2004. Survey subjects were selected independently and uniformly throughout each year to represent the approximately 109 000 each of men and women non-institutionalized residents aged 35–74 years. Annual participation rates ranged from 57 to 65%. Further details on the survey procedures have been published elsewhere (Galobardes *et al.,* 2003).

Assessment of dietary salt from food items
A self-administered semi-quantitative food frequency questionnaire (FFQ), developed and tested in the target population, was completed (Morabia *et al.,* 1994). It asks about consumption frequencies and quantities during the previous 4 weeks of 91 fresh and prepared food items organized by food groups (dietary supplements not counted). It does not assess discretionary salt usage, that is, salt and salt-containing condiments added during preparation/cooking of food or at the table.

Our original daily dietary assessments that relied on a modified 1991 French CIQUAL food composition table (Centre Informatique sur la Qualité des Aliments et Fondation Française pour la Nutrition, 1991) are described elsewhere (Bernstein *et al.,* 1994). Our previous use of the food composition table did not include sodium. We therefore performed a retrospective compilation of data on food sodium content based on two sources, the 1991 French CIQUAL table and the new Swiss food composition table, Swiss Food Data (Swiss Federal Office of Public Health and Swiss Federal Institute of Technology Zurich, 2003). Attribution criteria of specific sodium values to food items included: best available data quality, that is, giving higher value to food composition data analyzed in local laboratories than to data derived from other international food composition tables or the literature; considering, where applicable, data for prepared vs raw food; and data on foods of either Swiss or French origin typically available to or consumed by the study population. We then derived an educated 'best' estimate of the sodium content of each food item.

One gram of sodium is equivalent to 2.548 g of salt, the conversion factor used to estimate grams of salt intake (DGE *et al.*, 2000; Scientific Advisory Committee on Nutrition, 2003).

A modified DAFNE Food Classification system (European Commission, 2005), accounting for the food groups employed in the French salt intake report (Agence française de sécurité sanitaire des aliments, 2002), was used for estimating salt intake by food groups.

Socio- and health-behavioral risk factor subgroups
Socioeconomic position was characterized by either occupation or education, separately. Occupations were grouped into three categories using the British Registrar General's Scale: high (I and II from the British classification: professional and intermediate professions); medium (III-N: non-manual occupations); and low (III-M, IV and V: manual or lower occupations). We used current occupation for those working at the time of the survey, and the longest occupation ever held for those not working at the time of the survey. Years of formal education were grouped as: high ($\geqslant$13, including the Swiss baccalaureate); medium (9–12); and low ($\leqslant$8).

Nationality (country of birth) was grouped into Switzerland, Mediterranean (Italy, Spain, Portugal) and other ($\approx$1/3 France; remaining countries, mostly Northern Europe, $<$5% each).

Body mass index (BMI) was calculated in $kg\,m^{-2}$. Overweight was defined as $25\,kg\,m^{-2} \leqslant BMI < 30\,kg\,m^{-2}$, obese as $BMI \geqslant 30\,kg\,m^{-2}$.

Ever cigarette smokers had smoked at least 100 cigarettes in their lifetime, current smokers reported having smoked during the year before their interview and ex-smokers reported having quit smoking for at least 1 year before their interview.

Alcohol drinking (g alcohol per day) was categorized approximately based on the gender-specific WHO criteria for risk of consumption on a single drinking day (World Health Organization, 2000), and was grouped (men/women) as follows: low (1–40/1–20 g per day); medium (41–60/21–40 g per day); high and very high (61+/41+ g per day).

Independent salt-validation substudy based on complete 24-h urine collections
Due to cost and feasibility, we did not estimate salt intake from sodium excretion in 24-h urine collections. Instead, the assessment of daily dietary sodium intake with the FFQ was validated against the sodium excretion in 24-h urine collections in an independent substudy. In 2005, a call for participation was publicized among the medical faculty, staff and general public of the Geneva University Hospital. A total of 38 male and 62 female volunteers aged 35–74 years from diverse socioeconomic backgrounds similar to those of the Bus Santé survey population were enrolled in the substudy (Beer-Borst *et al.,* 2006).

Briefly, the volunteers completed the FFQ and the general health questionnaire on average 6 days prior to their 24-h urine collection. The questionnaires were quality controlled individually and body weight, body height and blood pressure were measured. Urinary creatinine (urinary collection completeness check), sodium and potassium concentrations were analyzed at the Geneva University Hospital central laboratory by the Jaffé method (Synchron LX-20 Beckman Coulter) and by ion-selective electrodes (biffe flame photometry), respectively (Beer-Borst *et al.,* 2006).

Regression calibration and estimation of discretionary salt intake
Food frequency questionnaire sodium intakes for the 1993–2004 surveys were calibrated by applying the results of linearly regressing the 24-h urinary sodium excretions on the FFQ-estimated sodium intakes for the 100 participants in the independent validation substudy (Beer-Borst *et al.,* 2006). Discretionary salt intakes for the 1993–2004 main samples were then estimated by taking the differences between the calibrated and the pre-calibrated salt intakes.

Statistical analyses
The statistical methods (all stratified by gender) described in this section refer to the calibrated 1993–2004 survey data. Dietary salt intake was expressed in g per day, and dietary salt density was expressed in grams per megajoule ($g\,MJ^{-1}$) ($4.184\times10^{-3}\,MJ=1\,kcal$) of total energy intake. In some analyses, dietary energy-adjusted salt intake (salt density) *excluding* energy from alcohol, was employed as the outcome variable.

Linear regression models applied to the individual participant (un-aggregated) salt intake and salt-density data were used to estimate annual means with 95% confidence interval limits and to assess time trends. The survey year regression slopes measured the annual changes in the mean dietary salt intake and salt density (Costanza, 2004). The linear regression-estimated annual means, together with the raw annual means, were depicted graphically to provide some idea of background sampling fluctuations. The *P*-value was used to test the null hypothesis that the slope = 0 (no trend) across the regression-estimated annual means.

For assessing overall salt intake and salt-density differences by age, the 25th, 50th (median), and 75th percentiles (P25, P50, P75) stratified by 5-year age subgroups were plotted and linear regression methodology analogous to that described above was employed to test the null hypothesis that the age subgroup slope = 0 (no age effect).

Age-adjusted multiple linear regression models were employed to compare daily salt-density means between the subgroups defined by each of the individual socio- and health-behavioral risk factors, occupation, nationality, BMI, cigarette smoking and alcohol drinking. In addition to age adjustment, the comparisons between subgroups for a given risk factor were simultaneously adjusted for all the other risk factors included in the models.

Results

Independent salt-validation substudy calibration
In the salt-validation substudy, the FFQ underestimated the respective daily crude salt intake and salt density compared to the urinary measures by an average 2.8 g per day and $0.40\,g\,MJ^{-1}$ for women and by 3.6 g per day and $0.45\,g\,MJ^{-1}$ for men. The mean ratio between the urinary and the calculated salt-intake measures was 1.7 in both genders (Beer-Borst *et al.,* 2006).

The linear regression calibration equations for estimating 24-h urinary excretion of sodium from the FFQ were:

$$8.20 + 0.38 * \text{FFQ in men } (r = 0.31,\ P = 0.054), \text{ and}$$
$$4.55 + 0.67 * \text{FFQ in women } (r = 0.45,\ P = 0.00028).$$

The mean 1993–2004 calibrated salt intakes were 10.6 g per day in men and 8.1 g per day in women. The remainder of the results refer to the calibrated 1993–2004 survey data.

Twelve-year trends and age differences in calibrated dietary salt intake and salt density
Calendar year and overall age subgroup variations in crude salt intakes and energy-adjusted salt intakes (densities), respectively, are shown in Figures 1 and 2. Overall, men had significantly higher crude and energy-adjusted salt intakes than women (both $P<0.0001$). In both genders, however, these two salt measures were very stable during the 12-year surveillance period (Figures 1 and 2, top). Similar results were obtained by restricting the analyses to subjects not treated for hypertension (data not shown). Thus, all subsequent results are reported for all survey years and across treated and untreated individuals combined.

There was little evidence of consistent age differences in crude dietary salt intakes in men, and only weak evidence of an increase with age in women ($P<0.056$) (Figure 1, bottom). Dietary salt densities tended to increase significantly with age in men ($P<0.001$), and somewhat (but less consistently so) in women ($P<0.018$) (Figure 2, bottom).

Overall dietary salt intake and salt density
The overall distributions of crude salt intake and salt density, respectively, are shown for men (top) and women (bottom) in Figures 3 and 4. The quartiles P25, P50, P75 (and mean) of salt intake were 9.9, 10.5, 11.2 (10.6) g per day in men, and 7.0, 7.8, 8.9 (8.1) g per day in women. The quartiles (mean) of salt density were 0.99, 1.16, 1.39 (1.23) $g\,MJ^{-1}$ in men, and 0.98, 1.12, 1.30 (1.17) $g\,MJ^{-1}$ in women.

Food sources of calibrated dietary salt intake
Table 1 lists food groups together with their relative contributions to the population total dietary salt intakes by gender. Mean discretionary salt use was estimated as 4.3 g per day in men and 2.8 g per day in women. Discretionary salt was the major single contributor to salt intake in both genders (men/women: 41/35%). However, the following five food groups contributed another 47% to the total salt consumed by men, and 48% to that consumed by women: breads (men/women: 17/17%), cheeses (11/10%), meat and meat products (8/7%), soups (6/9%) and ready-to-eat foods (5/5%). The contributions of the specific items in each food

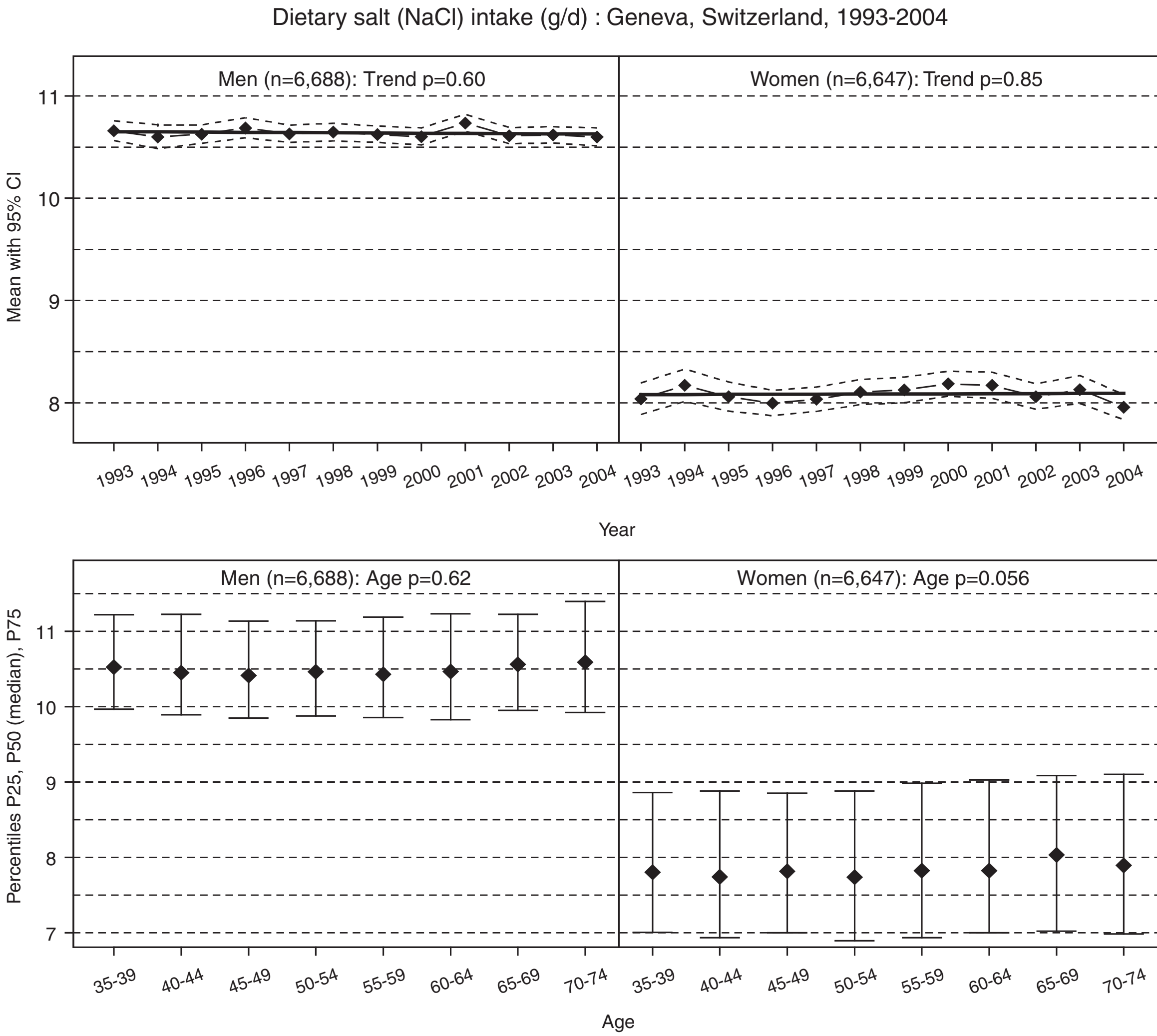

Figure 1 Twelve-year trends in crude dietary salt intakes (g per day) and overall percentiles by 5-year age subgroups. Trends (top): annual means indicated by diamonds with 95% confidence interval (CI) limits (dashed lines); solid lines represent linear regression-estimated means; *P* for testing that the annual slope = 0. Age groups (bottom): medians (50th percentiles) indicated by diamonds, error bars represent the 25th and 75th percentiles; *P* for testing that the annual slope = 0. (note: linear regression-estimated means > medians due to right-skewed distributions (see Figure 3)). Bus Santé, Geneva, Switzerland, 1993–2004.

group to total calibrated salt intake can be obtained upon request from the authors.

Age-adjusted multivariate associations with dietary salt density

The mean salt densities adjusted for age and all the other listed covariates included in the linear regression models are shown in Tables 2a and 2b. In both genders, the adjusted mean salt densities increased with BMI ($P<0.0001$) regardless of whether alcohol was included in or excluded from total energy intake. While the mean salt densities appeared to decrease with alcohol intake (Table 2a), this finding disappeared when alcohol was excluded from total energy intake (Table 2b). In fact, the food group sources for dietary salt intake exhibited only very minor differences between the various alcohol-drinking subgroups in both genders (data not shown otherwise).

Only in women, there was a significant monotonic increase in adjusted mean salt density with smoking status (never <ex-smoker <current smoker, $P<0.0001$) regardless of whether alcohol was included in or excluded from total energy intake (Tables 2a, 2b). A similar increase was found in men only when excluding alcohol from total energy intake (never < ex-smoker and never < current smoker, $P=0.0009$, Table 2b).

There were no statistically significant differences for either gender between occupation or nationality subgroups in the age-adjusted multivariate analyses (Tables 2a, 2b). The

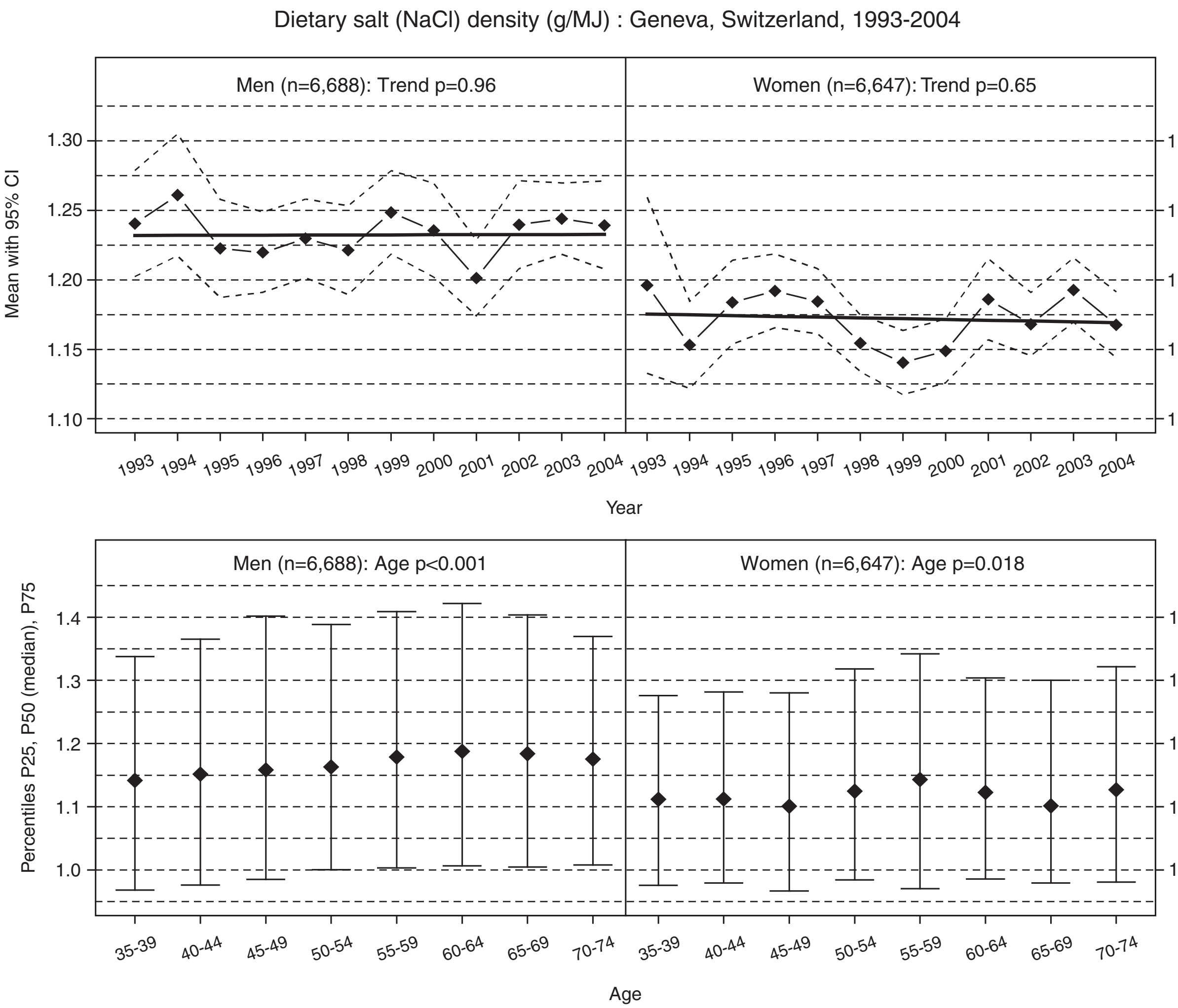

Figure 2 Twelve-year trends in dietary salt densities (g MJ^{-1}) and overall percentiles by 5-year age subgroups. Trends (top): annual means indicated by diamonds with 95% confidence interval (CI) limits (dashed lines); solid lines represent linear regression-estimated means; *P* for testing that the annual slope = 0. Age groups (bottom): medians (50th percentiles) indicated by diamonds, error bars represent the 25th and 75th percentiles; *P* for testing that the annual slope = 0. Bus Santé, Geneva, Switzerland, 1993–2004.

analogous models with education substituted for occupation led to very similar results, hence are not shown.

Discussion

Assessment of dietary salt intake via FFQ and 24-h urine excretion
The validated semi-quantitative FFQ used in our study provides information on the habitual dietary intakes of the Geneva adult population. It is well known that FFQ-estimated levels of nutrient intakes are approximations. On the other hand, FFQs are appropriate tools for ranking subjects according to their food and nutrient intakes (Thompson and Byers, 1994). In the basic development and validation process of the FFQ, sodium was not considered as one of the key nutrients. Underestimation of sodium intake from foods may be due to the limited food list and the fact that discretionary salt (salt and sodium or salt-containing condiments used during food preparation and at the table) was not specifically listed.

Twenty-four hour urinary excretion of sodium accounts for up to 95–98% of true dietary exposure and is considered the most accurate measure available for quantification of total sodium or salt intake (Bates *et al.*, 1997). However, this biochemical marker estimates total amounts of salt intake accurately only when complete urine collections are obtained, or else when incomplete results have been corrected using a marker for completeness of collection (Bates *et al.*, 1997; Scientific Advisory Committee on Nutrition, 2003). In surveillance of a large probability sample of a general adult population, routine full 24-h urine sample collection is demanding and difficult (Bates *et al.*, 1997; Henderson *et al.*,

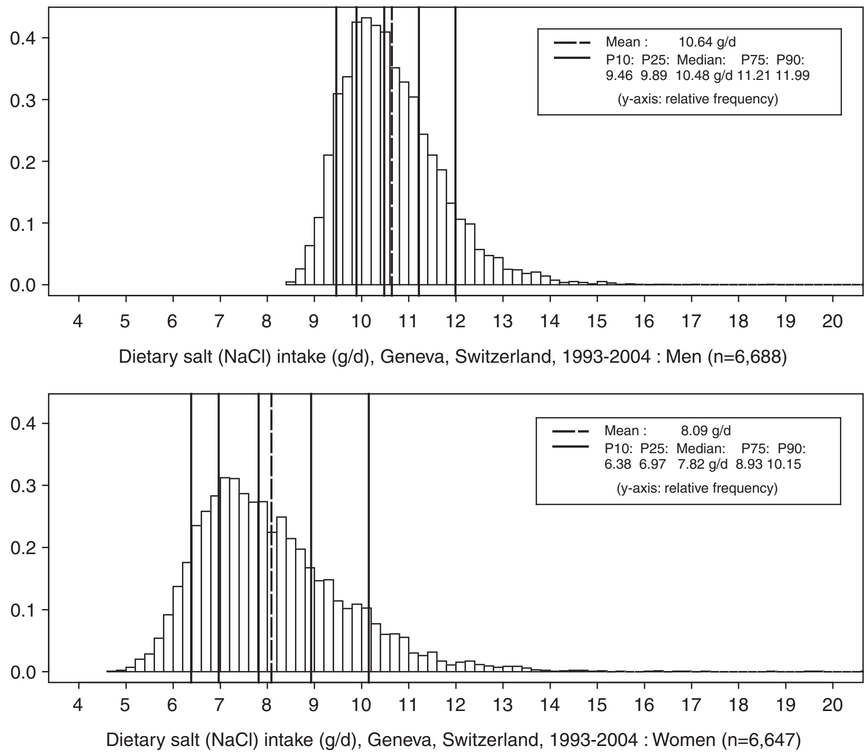

Figure 3 Overall distributions of crude dietary salt intakes (g per day, *including* energy from alcohol) by gender, with means and the 10th, 25th, 50th (median), 75th and 90th percentiles. Bus Santé, Geneva, Switzerland, 1993–2004.

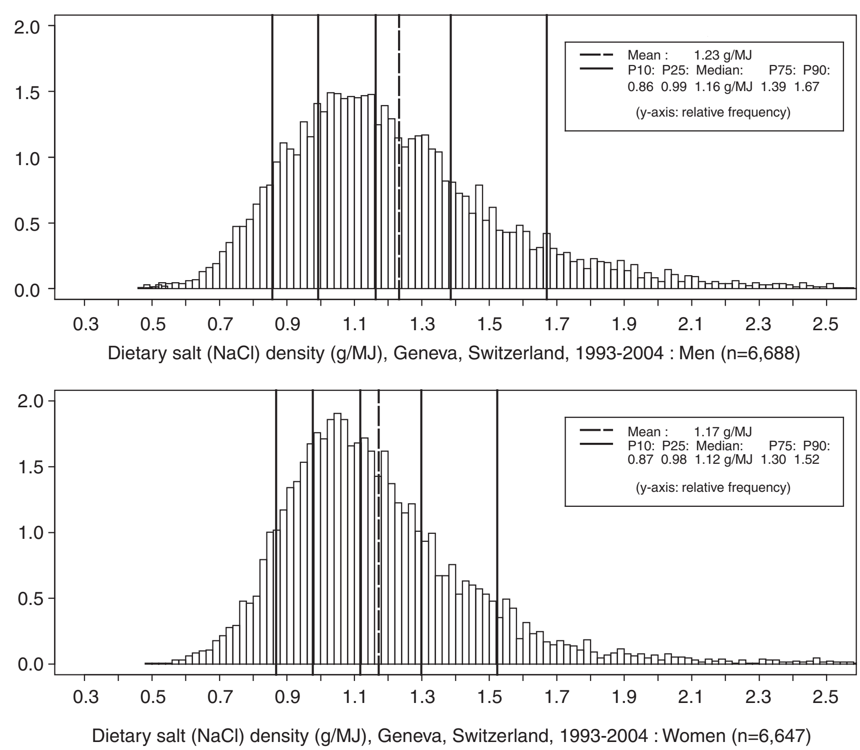

Figure 4 Overall distributions of dietary salt densities (g MJ^{-1}, *including* energy from alcohol) by gender, with means and the 10th, 25th, 50th (median), 75th and 90th percentiles. Bus Santé, Geneva, Switzerland, 1993–2004.

Table 1 Food group sources of calibrated dietary salt intake (mean) by gender. Bus Santé, Geneva, Switzerland, 1993–2004

Food groups (in decreasing order for men and women combined)	*Men* (n = *6688)*			*Women* (n = *6647)*		
	g per day	*%* [a]	*Cumulative %*	*g per day*	*%* [a]	*Cumulative %*
Discretionary salt[b]	4.3	41	41	2.8	35	35
Breads	1.8	17	58	1.4	17	52
Cheeses	1.2	11	69	0.8	10	62
Meat (including cold cuts), liver, eggs	0.8	8	77	0.6	7	69
Soups	0.6	6	83	0.7	9	78
Ready-to-eat foods	0.5	5	88	0.4	5	83
Sea food (fish, shellfish)	0.3	3	91	0.3	4	87
Sauces and dressings	0.3	3	94	0.4	5	92
Croissants, cakes, pastries	0.3	3	97	0.2	2	94
Other dairy (except cheeses, milk)	0.1	1	98	0.2	2	96
Vegetables	0.1	1	99	0.1	1	97
Breakfast cereals	0.1	1	—	0.1	1	98
Milk	0.1	1	—	0.1	1	99
Potatoes and potato products	0.1	1	—	<0.1	<1	—
Water (including coffee/tea)	<0.1	1	—	<0.1	<1	—
Fruits and fruit products	<0.1	<1	—	<0.1	<1	—
Alcoholic beverages	<0.1	<1	—	<0.1	<1	—
Other beverages	<0.1	<1	—	<0.1	<1	—
Fat spreads	<0.1	<1	—	<0.1	<1	—
Cereals (starchy foods)	<0.1	<1	100	<0.1	<1	100
Total calibrated salt intake	10.6	100		8.1	100	

[a]Percentages sum to more than 100 due to rounding.
[b]Difference between calibrated and pre-calibrated total salt intake. See Methods.

Table 2a Dietary, total energy (*including* alcohol)-adjusted salt intake (salt density, $g\,MJ^{-1}$) linear regression multivariate adjusted means and associations (adjusted for age and all other covariates in the table) with socio- and health-behavioural characteristics by gender. Bus Santé, Geneva, Switzerland, 1993–2004

Characteristic	*Subgroup*	*Men* (n = *6370)*[a]				*Women* (n = *6063)*[a]			
		n	*Mean (s.e.m.)*	*Overall* P	*Difference* P *< 0.05*	n	*Mean (s.e.m.)*	*Overall* P	*Difference* P *< 0.05*
Occupation	High	3116	1.17 (0.010)			1954	1.13 (0.013)		
	Medium	1458	1.19 (0.012)	0.37	None	3246	1.13 (0.010)	0.94	None
	Low	1796	1.17 (0.012)			863	1.14 (0.013)		
Nationality[b]	Switzerland	3569	1.17 (0.009)			3329	1.13 (0.010)		
	Other	1745	1.19 (0.011)	0.19	None	1940	1.14 (0.011)	0.68	None
	Mediterran.	1056	1.19 (0.013)			794	1.13 (0.014)		
BMI[c]	Normal	2711	1.14 (0.010)		Normal weight <	4056	1.10 (0.009)		Normal weight <
	Overweight	2790	1.19 (0.009)	<0.0001	Overweight <	1431	1.13 (0.011)	<0.0001	Overweight <
	Obese	869	1.22 (0.014)		Obese	576	1.17 (0.016)		Obese
Smoking	Never	2258	1.17 (0.011)			3176	1.11 (0.010)		Never <
	Ex-smoker	2290	1.18 (0.010)	0.14	None	1408	1.14 (0.012)	<0.0001	Ex-smoker <
	Current	1822	1.19 (0.011)			1479	1.16 (0.011)		Current
Alcohol drinking[d]	Non-drinker	511	1.37 (0.017)		Non-drinker >	1196	1.26 (0.010)		Non-drinker >
	Low	4867	1.27 (0.007)	<0.0001	Low >	4240	1.20 (0.007)	<0.0001	Low >
	Medium	575	1.09 (0.016)		Medium >	432	1.09 (0.017)		Medium >
	High/very high	417	0.99 (0.018)		High/very high	195	0.98 (0.024)		High/very high

[a]Individuals with any missing data (5% of men, 9% of women) excluded from these analyses.
[b]Other: mostly France and Germany; Mediterranean: Italy, Spain, Portugal.
[c]Body mass index ($kg\,m^{-2}$): BMI < 25; overweight: 25 ⩽BMI <30; obese: BMI ⩾30.
[d]Grams alcohol per day (men/women): low, 1–40/1–20; medium, 41–60/21–40; high/very high, 61+/41+.

Table 2b Dietary, energy (*excluding* alcohol)-adjusted salt intake (salt density, g MJ^{-1}) linear regression multivariate adjusted means and associations (adjusted for age and all other covariates in the table) with socio- and health-behavioural characteristics by gender. Bus Santé, Geneva, Switzerland, 1993–2004

Characteristic	*Subgroup*	*Men* (n = *6370*)[a]				*Women* (n = *6063*)[a]			
		n	*Mean (s.e.m.)*	*Overall* P	*Difference* P < *0.05*	n	*Mean (s.e.m.)*	*Overall* P	*Difference* P < *0.05*
Occupation	High	3116	1.36 (0.012)			1954	1.26 (0.012)		
	Medium	1458	1.36 (0.014)	0.36	None	3246	1.25 (0.014)	0.83	None
	Low	1796	1.34 (0.011)			863	1.25 (0.011)		
Nationality[b]	Switzerland	3569	1.34 (0.011)			3329	1.25 (0.011)		
	Other	1745	1.35 (0.015)	0.20	None	1940	1.26 (0.012)	0.68	None
	Mediterran.	1056	1.36 (0.013)			794	1.25 (0.015)		
BMI[c]	Normal	2711	1.31 (0.011)		Normal weight <	4056	1.22 (0.012)		Normal weight <
	Overweight	2790	1.36 (0.011)	<0.0001	Overweight	1431	1.25 (0.012)	<0.0001	Overweight <
	Obese	869	1.39 (0.011)		Normal weight < Obese	576	1.29 (0.017)		Obese
Smoking	Never	2258	1.33 (0.012)		Never <	3176	1.22 (0.011)		Never <
	Ex-smoker	2290	1.35 (0.012)	0.0009	Ex-smoker	1408	1.26 (0.013)	<0.0001	Ex-smoker <
	Current	1822	1.38 (0.012)		Never < Current	1479	1.29 (0.012)		Current
Alcohol drinking[d]	Non-drinker	511	1.38 (0.021)			1196	1.27 (0.011)		
	Low	4867	1.36 (0.008)	0.23	None	4240	1.25 (0.008)	0.34	None
	Medium	575	1.34 (0.019)			432	1.25 (0.018)		
	High/very high	417	1.33 (0.021)			195	0.26 (0.026)		

[a]Individuals with any missing data (5% of men, 9% of women) excluded from these analyses.
[b]Other: mostly France and Germany; Mediterranean: Italy, Spain, Portugal.
[c]Body mass index (kg m^{-2}): BMI < 25; overweight: 25 ⩽BMI <30; obese: BMI ⩾30.
[d]Grams alcohol per day (men/women): low, 1–40/1–20; medium, 41–60/21–40; high/very high, 61+/41+.

2003), and may even be impractical because of the technical challenges and the risk of poor compliance.

Nonetheless, certain exemplary surveys, such as The British National Diet & Nutrition Survey for adults aged 19–64 years (Henderson *et al.,* 2003), measured sodium intakes from food by weighed dietary records, frequency of discretionary salt use by interviews and sodium intake from all sources by urine collections. In the Finnish risk factor surveys (Pietinen *et al.,* 1996), sodium intake was assessed in the years 1979/82/87 in a subsample of the survey participants by 24-h urine collection.

Since commonly used dietary questionnaire-based assessment methods alone do not accurately quantify total dietary sodium/salt intakes, specific approaches have been used to assess discretionary salt use. One involves a validated method of exclusively using lithium-tagged salt for discretionary salt in participating households, combined with 24-h urine collections. In two community-based trials, this method estimated discretionary salt contributions to daily salt intake ranging from 15 (1.75 g per day) (Sanchez-Castillo *et al.,* 1987) to 36–39% (3.94 g per day) (Leclercq and Ferro-Luzzi, 1991). Another approach involves calculating the difference between complete 24-h urine sodium excretion and dietary sodium intake assessed by questionnaire, as done in the British adult National Diet & Nutrition Survey (Henderson *et al.,* 2003). Discretionary salt accounted for 23 (2.52 g per day) and 28% (2.25 g per day) of total daily sodium intake in men and women, respectively.

We applied the latter approach in our validation substudy, upon which we then based the calibration of the 1993–2004 survey data. We estimated higher discretionary salt contributions to total salt intake of 35% (2.8 g per day) in women and 41% (4.3 g per day) in men. It is noteworthy that the latter post- minus pre-calibration differences probably account not only for added salt. Other sodium-/salt-containing foods that are not listed among the specific 91 food items on the Geneva FFQ may have to be accounted for, particularly in men. Further shortcomings are the lacking detail and accuracy of the used food composition table with respect to sodium content of foods and dishes, and the fact that urinary sodium excretion accounts only for about 95% of real salt intake.

More comprehensive dietary assessment tools such as those employed in the British and Finnish studies have many strengths, but also some weaknesses. They may not be able to assess a population's average dietary intake more accurately than the validation–calibration approach employed in the present study.

Determinants of dietary salt intake and density and relative importance of different food sources to overall salt intake

Crude salt intakes among Geneva adults did not vary appreciably with age, but salt densities increased with age in both genders. This might be explained by reduced energy needs and hence a certain expected decrease in food (energy) intake at older ages, as well as with a preference for saltier foods or use of relatively more discretionary salt to compensate for age-related reductions in taste perception.

Other major determinants of salt density were relative weight (BMI) and, mainly in women, smoking status. Female current and ex-smokers preferred a saltier diet than non-smokers. It could be hypothesized that nicotine and cigarette smoking reduces the perception and/or hedonics of salty taste. Moreover, overweight and obese individuals were shown to have a qualitatively different diet with respect to salt (salt-containing foods or discretionary salt use) compared to individuals of normal weight, which should be considered when targeting cardiovascular risk factor subgroups.

Apart from discretionary salt, breads, cheeses, meat and meat products and convenience-type foods such as soups, pizza, and so on, were the main food sources of dietary salt in Geneva (and perhaps in Switzerland).

Comparisons with other population surveys

Results similar to ours have been reported by dietary surveys in France (Agence française de sécurité sanitaire des aliments, 2002), Germany (aid, 2002) and the United Kingdom (Henderson *et al.,* 2003). Direct comparisons across surveys are limited, however, because single foods were grouped differently by the various studies.

Surveys employing 24-h urine collections found similar salt intakes to those estimated after calibration in Geneva (means 10.6 g per day in men, 8.1 g per day in women). In the British adult National Diet & Nutrition Survey, mean salt intakes from 24-h urine excretion were about 11 g per day in men and 8 g per day in women (Henderson *et al.,* 2003). In Italy, mean intakes of 11 g per day in men and 9.4 g per day in women were reported across three regions (Leclercq and Ferro-Luzzi, 1991). In three Finnish regions in 2002, the calculated mean salt intake from 24-h urine collections ranged from 8.6 to 9.8 g per day in men and from 6.9 to 7.4 g per day in women (Laatikainen *et al*., 2006). Considering a 90% sodium recovery in urine, these authors estimated salt intakes, for example, in North Karelia, to be effectively around 10.5 g per day in men and 8.2 g per day in women.

Comparisons with current recommendations

There have been decades of controversy over whether a universal reduction of sodium/salt intake has been scientifically substantiated for lowering blood pressure and improving cardiovascular health in general populations (Kaplan, 2000; McCarron, 2000, 2001; Strazzullo, 2001; Alderman, 2002). Some consensus seems to have been reached that a modest reduction of salt intakes down to levels of 5–6 g per day over a prolonged period of time has a pronounced effect on blood pressure in both hypertensive and normotensive populations (for example, Elliott and Stamler, 2002; He and Whelton, 2002; MacGregor and de Wardener, 2002).

The Joint WHO/FAO Expert Consultation on diet, nutrition and the prevention of chronic disease recommended limiting daily salt intake to at most 5 g per day to control blood pressure levels and reduce hypertension prevalence and related health risks in populations (Joint WHO/FAO Expert Consultation, 2003). National recommendations diverge slightly from this. In the United Kingdom, an 'achievable' level of salt consumption has been defined as 6 g per day (Scientific Advisory Committee on Nutrition, edn 2003), with a further suggestion that considering gender differences in energy intakes, this amount should be corrected to 7 g per day for men and 5 g per day for women. In France, only a moderate population-wide reduction in salt intake down to 6–8 g per day was recommended (Agence française de sécurité sanitaire des aliments, 2001). German, Austrian and Swiss nutrition societies state that a dietary salt intake of up to 6 g per day is likely to be 'sufficient', but otherwise do not provide a more restricted target level (DGE *et al*., 2000).

Our calibration-estimated mean total crude (energy-adjusted) salt intakes exceed all of these dietary salt target levels. Although our estimates for total salt intake may still underestimate true salt intakes in our population, reduction of average population salt intakes to 6 g per day may be a feasible goal. Finnish health authorities, for example, have been active for several decades to gradually reduce absolute salt intakes in adults to levels recommended by the Finnish National Nutrition Council (2005), which are at present 7 g per day for men and 6 g per day for women.

Conclusions

Salt intakes from 'all' sources for Geneva adults are about 3–5 g above current recommendations. It appears that the best strategy would be to reduce the salt content in frequently consumed processed and prepared foods in cooperation with the food industry.

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Conflicts of interest

None declared.

Ethical approval

The surveys were approved by the ethical committee for epidemiological research and public health, Institute for

Social and Preventive Medicine at the University of Geneva. The salt intake validation study was approved by the Geneva University Hospital institutional ethics committee.

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