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Salt intakes around the world: implications for public health

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Background High levels of dietary sodium (consumed as common salt, sodium chloride) are associated with raised blood pressure and adverse cardiovascular health. Despite this, public health efforts to reduce sodium consumption remain limited to a few countries. Comprehensive, contemporaneous sodium intake data from around the world are needed to inform national/international public health initiatives to reduce sodium consumption.

Methods Use of standardized 24-h sodium excretion estimates for adults from the international INTERSALT (1985–87) and INTERMAP (1996–99) studies, and recent dietary and urinary sodium data from observational or interventional studies—identified by a comprehensive search of peer-reviewed and 'grey' literature—presented separately for adults and children. Review of methods for the estimation of sodium intake/excretion. Main food sources of sodium are presented for several Asian, European and Northern American countries, including previously unpublished INTERMAP data.

Results Sodium intakes around the world are well in excess of physiological need (i.e. 10–20 mmol/day). Most adult populations have mean sodium intakes >100 mmol/day, and for many (particularly the Asian countries) mean intakes are >200 mmol/day. Possible exceptions include estimates from Cameroon, Ghana, Samoa, Spain, Taiwan, Tanzania, Uganda and Venezuela, though methodologies were sub-optimal and samples were not nationally representative. Sodium intakes were commonly >100 mmol/day in children over 5 years old, and increased with age. In European and Northern American countries, sodium intake is dominated by sodium added in manufactured foods (~75% of intake). Cereals and baked goods were the single largest contributor to dietary sodium intake in UK and US adults. In Japan and China, salt added at home (in cooking and at the table) and soy sauce were the largest sources.

Conclusions Unfavourably high sodium intakes remain prevalent around the world. Sources of dietary sodium vary largely worldwide. If policies

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for salt reduction at the population level are to be effective, policy development and implementation needs to target the main source of dietary sodium in the various populations.

Keywords Salt, sodium, dietary, urinary, blood pressure, cardiovascular disease prevention

Introduction

High levels of dietary sodium (consumed as common salt, sodium chloride) are associated with raised blood pressure (BP) and adverse cardiovascular health.[1] Animal experiments, epidemiological studies and clinical trials provide compelling evidence for a detrimental effect of sodium intake on BP among both hypertensive and normotensive individuals.[2–8] In addition to its effects on BP, excess dietary sodium consumption has been associated directly with coronary heart disease (CHD),[9,10] stroke[11] and non-cardiovascular diseases.[12]

Sodium intakes of different populations around the world were first brought to the attention of the research community by publication of Louis Dahl's famous graph in 1960, showing a positive linear relationship between prevalence of hypertension and mean sodium intake across five populations.[13] He noted that daily intakes of sodium varied considerably across population groups from 68 mmol/day among Alaskan Eskimos to 462 mmol/day in Akita prefecture, northeast Japan. American men had intermediate intakes averaging 171 mmol/day. He also noted a strong north–south trend in death rates from stroke in Japan, which coincided with differences in sodium intake ranging from 239 mmol/day in the south to 462 mmol/day in the northeast. The extremely high sodium intakes in the northeast reflected the dietary practice of eating rice with miso soup and pickles, and the use of soy sauce as seasoning.[14]

Dahl's observations on five populations were expanded by other authors.[15,16] Gleiberman[15] provided estimates of sodium intakes in 27 populations around the world, including both measured data and her own estimates. Froment *et al*.[16] used published data based mainly on 24-h urinary sodium excretion to compare sodium intakes from 28 populations. Reported salt intake varied from 1 mmol/day among the Yanomamo Indians of Brazil to 385 mmol/day in Korea and the Bahamas.[17–19] Nine isolated populations had salt intakes of <35 mmol/day. Subsequently, the INTERSALT Study provided standardized estimates of sodium intakes from 52 population samples in 32 countries based on data from 24-h urinary collections.[8,20]

Despite the wealth of evidence for unfavourable effects of salt consumption on BP and cardiovascular health, public health efforts to decrease sodium consumption have been limited to a few countries.[21–24] Individuals are often unaware of the detrimental effect of salt on health[25] and in developed countries, the majority of salt consumed is hidden in processed foods.[26,27] The aims of the present report are: (i) to present a comprehensive overview of salt intakes around the world in both adults and children; (ii) estimate contemporary intake levels; and thus (iii) provide the basis for public health initiatives to reduce sodium intakes and the related burden of cardiovascular and other diseases.

Methods

Sodium intake estimates include the extensive standardized population data on 24-h urinary sodium excretion from the INTERSALT Study,[28] and on sodium intakes and 24-h urinary sodium excretion from the subsequent International Study of Macro- and Micro-Nutrients and Blood Pressure (INTERMAP).[29] INTERSALT collected standardized data on 24-h urinary excretion of sodium among 10 079 men and women aged 20–59 years from 52 population samples in 32 countries—by far the most extensive set of standardized data on 24-h urinary sodium excretion patterns around the world.[8,20] Data collection took place between 1985 and 1987. To guard against under- and over-collection, both start and end times of the urine collections were supervised by clinic staff. Urine collections were rejected if the participant answered that 'more than a few drops' were missing from the collection, if urinary volumes were <250 ml, or if the timing of the collection fell outside the range 20–28 h. Eight percent of the study sample collected a second 24-h urinary specimen 3–6 weeks later to estimate within-individual variability of sodium excretion.

INTERMAP included measurements of dietary sodium intake and urinary sodium excretion from men and women, aged 40–59 years, from 17 population samples in Japan (four samples), People's Republic of China (PRC, three samples), UK (two samples) and USA (eight samples).[29] Data collection took place between 1996 and 1999. Each participant had two study visits on consecutive days, with two additional study visits on consecutive days 3–6 weeks later. Measurements included dietary intake based on four multiple-pass 24-h dietary recalls (one at each study visit).[29,30] All foods and beverages consumed in the previous 24-h, including dietary supplements, were recorded. Two timed 24-h urine samples, started at the research centre (on the first and third study visits) and completed the next day, were obtained from each participant using the methods developed for INTERSALT.[31] Quality control was extensive, with local, national and international checks on the completeness and integrity of non-dietary and dietary information.[29,30] Individuals were excluded if (*inter alia*) diet data were considered unreliable, energy intake from any 24-h dietary recall was <2100 kJ/day or was >21 000 kJ/day for women or >33 600 kJ/day for men, or if two complete urine samples were not obtained.

We augment INTERSALT and INTERMAP data with reference here to the historical literature on sodium intakes and BP[13–16,32] and with data from peer-reviewed and 'grey' literature from 1988 to the present. Estimates of sodium intake in children and young adults were obtained from a literature search (see below), and from key reviews by Lambert *et al*.[33] and Simons-Morton and Obarzanek.[34] These summarize the available data on children's intakes from national surveys and observational studies of sodium intake and BP, respectively.

Search strategy

We carried out a search of the peer-reviewed literature on survey methods, sources of sodium in the diet and dietary surveys of sodium intake that have been published from 1988 onwards. Papers potentially to be included in our report were identified by: (i) a comprehensive keyword search of Medline and Thompson ISI Web of Science databases (keywords listed in Table S1 (Supplementary data are available at *Int J Epidemiol* online) (ii) a Web of Science cited reference search identifying papers that have cited the INTERSALT Study; (iii) examination of resulting reference lists; and (iv) authors' own knowledge and contacts. The search was essentially confined to the English literature, though non-English-language papers were included if identified by English keywords. Non-English-language grey literature was also considered.

Abstracts were reviewed and deemed 'not relevant', 'of potential interest' or 'of definite interest'. Those deemed 'not relevant' were rejected on the grounds that they did not appear to include data on sodium intake; efforts were made to obtain full copies of the remaining publications for review. Inclusion criteria were: (i) community-based study; (ii) observational design, or interventional design with baseline data; and (iii) mean dietary sodium intake or urinary excretion rate (amount/time) reported. Nationally representative data were included where available. Where more than one method was used to measure sodium we report only one, in the following order of preference: (a) 24-h urine collection; (b) duplicate food portion, multi-day weighed dietary record or 24-h dietary recall; and (c) overnight or <24-h urine collection with urine volume reported. Data on sodium concentration or sodium/creatinine ratio were excluded, as absolute excretion rates could not be calculated.[35–39]

Units

Sodium intake is usually reported as either mass or millimolar amounts of sodium, or as mass of sodium chloride (salt). Here we refer mainly to dietary sodium and not to dietary salt (1 g sodium chloride = 17.1 mmol sodium). For ease of comparison all dietary and urinary estimates were converted to millimolar sodium per day (1 mmol sodium = 23 mg). Wherever possible, given estimates of variability were converted to standard deviations based on approximate normality of distributions.

The measurement of dietary sodium intake

As noted, the studies included in this review use different methods to estimate sodium intake, falling into two broad categories: (i) estimates based on urinary sodium excretion; and (ii) estimates based on dietary survey—each with its own strengths and limitations.

Estimates based on urinary sodium excretion

Because of the problems of underestimation of sodium intakes based on dietary surveys in most studies, 24-h urinary sodium excretion has become the preferred method of obtaining data on sodium intakes in population surveys.[40–42] A 24-hour period is necessary to capture the marked diurnal variation in sodium, chloride and water excretion. Electrolyte excretion in healthy individuals reaches a maximum at or before midday, and a minimum at night towards the end of sleep.[43]

The 24-h urinary excretion method takes no account of electrolyte loss other than via the kidney, and therefore will tend to underestimate true intake. For example, among 28 adults average urinary excretion of sodium from seven consecutive 24-h urine collections was 86% of that estimated from chemical analysis of duplicate diets, collected over the same 7-day period.[44] Losses of sodium in the faeces are small;[45,46] losses through sweat are minimal in temperate climates but can be considerable in certain conditions.[47]

Unlike most dietary methods, the 24-h urine collection is not prone to reporting biases; however: (i) participant burden is high and therefore rates of attrition may be high; (ii) the collection must be complete, or near-complete, otherwise the excretion estimate will be biased; (iii) there is no absolute check on completeness [though the sodium/creatinine ratio and para-aminobenzoic acid (PABA) marker have been used—the latter mainly in validation studies];[48–51] and (iv) the collection must be accurately timed to avoid over- as well as under-collection and so that minor deviations from a 24-h collection period can be corrected. Data from studies with standardized methods, such as INTERSALT, INTERMAP and national surveys, including the UK Diet and Nutrition Survey, demonstrate that sodium excretion estimates are reproducible at population level, though there is well-known marked intra-individual variability (reflecting day-to-day variation in a person's sodium intake) at individual level.[52]

Overnight urine collections are a low-burden alternative to 24-h collection as fewer voidings are required, and the participant does not have to continue the collection during daily activities. As a result, a higher rate of compliance is likely in large epidemiological surveys.[53] The collection begins once the participant has voided before bed (urine is discarded), and the time is recorded. All urine voided during the night, and the first void in the morning upon rising, constitute the overnight collection. Sodium excretion is calculated and corrected to an 8-h base.[54] Despite these advantages in terms of participant burden and compliance, overnight urine collections may be biased because of the marked diurnal variation in sodium excretion.[43] This varies between individuals depending on factors including sodium intake, gender and race, and in hypertensive individuals, usual diurnal pattern may be reversed, with a greater proportion of sodium load being excreted at night.[54–57]

Estimates based on dietary survey

Foods consumed by an individual over a set period are recorded and these data are converted into nutrient intakes via standardized food tables. This approach is vulnerable to reporting errors, inaccurate or incomplete food composition tables, coding errors and sampling bias.[40] Specific problems for estimating sodium intake include: quantifying accurately the amount of sodium chloride added during cooking (including at restaurants) and at the table; variation in the proportion of salt added during cooking that is retained by the food (i.e. salt left behind on the plate); and variation in the sodium content of manufactured foods and in the sodium concentration of local water supplies.[26,40] The sodium content of processed and restaurant foods is especially important, as these contribute three-quarters or more of the sodium intake of a typical western diet.[26,27] As a consequence of the above, sodium intake estimates based on the food diary, weighed records, food-frequency questionnaire or 24-h dietary recall tend to underestimate sodium intakes as compared with intakes estimated from duplicate diets or 24-h urine collections.[49,58–61] A notable exception is the INTERMAP study, where similar estimates of sodium intake were obtained from the average of four 24-h dietary recalls and two 24-h urine collections for participants in Japan, UK and USA (but not PRC, where 24-h dietary recall estimates were lower than urinary estimates).[29]

Results

INTERSALT study

Among the 52 population samples included in INTERSALT, lowest mean values of sodium excretion were found among the Yanomamo Indians of Brazil: 0.8 mmol/day in men and 1.0 mmol/day in women (see Appendix Tables in *J Hum Hypertens* INTERSALT Special Issue).[28] Three other remote population groups had mean 24-h urinary sodium excretion of ~50 mmol/day or below: Xingu Indians of Brazil, Papua New Guinea Highlanders and the Luo in rural Kenya. Highest mean urinary sodium excretion was recorded in Tianjin, PRC: 259 mmol/day in men and 233 mmol/day in women. Urinary sodium excretion in Nanning in southern China was lower than in the other two Chinese samples: 177 mmol/day in men and 161 mmol/day in women. The highest mean urinary sodium excretion in Japan was found in Toyama: 224 mmol/day in men and 201 mmol/day in women. Mean values >200 mmol/day in men were also found in Canada, Columbia, Hungary, Ladakh (India), Bassiano (Italy), Poland, Portugal and South Korea. Men had higher values of urinary sodium excretion than women: modal value was 150–199 mmol/day for men and 100–149 mmol/day for women.

INTERMAP study

Country- and gender-specific mean urinary sodium excretion data for INTERMAP participants are shown in Table 1; detailed tables of mean urinary excretion and dietary intake by age and population sample are available in *J Hum Hypertens* INTERMAP Special Issue.[29] As in INTERSALT, the highest mean values of urinary sodium excretion were found in PRC, ranging up to 299 mmol/day in men and 253 mmol/day in women in the Beijing sample, northern China. Again, mean urinary sodium excretion in southern China (Guangxi) was much lower: 150 mmol/day in men and 128 mmol/day in women. In the USA, mean 24-h urinary sodium excretion for the eight population samples were all in the range 180–190 mmol/day for men and ~130–150 mmol/day for women. For the four Japanese samples, mean 24-h urinary sodium excretion was in the range of 195–220 mmol/day in men and ~160–200 mmol/day in women. Average 24-h urinary excretion values for sodium in the two UK samples were 161 mmol/day in men and 127 mmol/day in women.

Figure S1 (Supplementary data are available at *Int J Epidemiol* online) shows the within-population sample distributions of 24-h urinary sodium excretion for men and women among each of the four countries in INTERMAP (with north and south China displayed separately). The vast majority of people in each of the countries had urinary sodium excretion of >100 mmol/day, and few had values <70 mmol/day. Note that because of the large day-to-day variability in urinary sodium excretion, especially among the

Table 1 Mean dietary intake or urinary excretion of sodium for adults from around the world: 1988–present

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
American/Western Samoa (1990–91)	Galanis *et al.*[63]	Individuals recruited from 46 villages and worksites in American Samoa, and nine villages in Western Samoa. Samoans with European or Asian ancestry were excluded	25–55 yr	Single 24-h dietary recall	455 American Samoans 491 Western Samoans	94.9 ± 66.1[a] 76.7 ± 61.0[a]	Approximately equal number of men and women
Australia (1995)	Beard *et al.*[125]	Systematic sample from the Hobart electoral role	18–70 yr	Single 24-h urine collection	87 men 107 women	170.0 ± 52.0 118.0 ± 42.0	
Barbados (1991–94)	Cooper *et al.*[64]	Random sample of general population from periurban areas including Bridgetown	⩾25 yr	Single 24-h urine collection	813 men and women	115.3 ± 53.5	Urinary sodium assessed for an unspecified subset of total population
Brazil (1990–92)	Moraes *et al.*[126]	Random sample of the general population from the city of Porto Alegre	18–35 yr	Single overnight urine collection	Family history of hypertension: 27 No family history of hypertension: 130	136.4 ± 64.8[b] 135.0 ± 73.2[b]	
Brazil (n/a)	Pavan *et al.*[68]	Non-random general population sample of Amazonian Rondonia district, stratified by age and sex	22–89 yr	Unspecified dietary method	370 men and women	171.2 ± n/a	
Brazil (1999–2004)	Bisi Molina *et al.*[127]	Random sample of inhabitants from the city of Vitoria	25–64 yr	Single overnight urine collection	764 men 899 women	214.0 ± 116.0[b] 186.0 ± 114.0[b]	
Cameroon (1991–94)	Cooper *et al.*[64]	Random sample of civil servants from Yaounde and rural villages from the same region	⩾25 yr	Single 24-h urine collection	Urban: 1361 Rural: 1467	54.3 ± 30.2 88.4 ± 47.7	Urinary sodium assessed for an unspecified subset of total population
Canada (1990–99)	Institute of Medicine,[105] citing Health Canada	Unspecified sample from 10 provinces	⩾19 yr	Unspecified dietary method	18 214 men and women	135.7 ± 234.7	
France (n/a)	du Cailar *et al.*[128]	Individuals attending outpatient clinic in Montpellier for detection of CVD risk factors	14–70 yr	Two 24-h urine collections	14–40 yr: 438 41–70 yr: 417	144.0 ± 54.0 147.0 ± 62.0	Approximately equal number of men and women Those with heart disease, atherosclerosis, diabetes, renal disease, severe obesity, history of alcohol abuse excluded

(continued)

Table 1 Continued

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
Finland (2002)	Laatikainen *et al.*[24]	Random sample stratified by age and sex from population lists of three areas	25–64 yr	Single 24-h urine collection	168 men (North Karelia) 128 men (South-western Finland) 127 men (Helsinki) 174 women (North Karelia) 156 women (South-western Finland) 156 women (Helsinki)	163.2 ± 65.5[c] 169.6 ± 75.6[c] 147.8 ± 92.0[c] 127.8 ± 48.5[c] 127.1 ± 49.7[c] 119.1 ± 52.9[c]	
Ghana (2001–02)	Cappuccio *et al.*[65]	Age-sex stratified random sample of general population from 12 villages from the Ashanti region	40–75 yr	Two 24-h urine collections at baseline	Intervention: 522 Control: 491	99.9 ± 44.7 102.5 ± 45.3	Villages were rural or semi-urban
Iran (1998)	Azizi *et al.*[35]	Random sample of households from two cities: Rasht and Sari	>2 yr	FFQ and 2 weeks weighed discretionary salt	Rasht: 340 Sari: 343	127.6 ± 80.4 131.8 ± 68.5	
Italy (n/a)	Pavan *et al.*[68]	Non-random general population sample from the towns of Mirano and Castelfranco Veneto, stratified by age and sex	22–89 yr	Unspecified dietary method	370 men and women	188.3 ± n/a	
Jamaica (1994–95)	Cooper *et al.*[64]	Random sample of general population from periurban areas including Spanish Town	⩾25 yr	Single 24-h urine collection	1257 men and women	143.6 ± 112.6	Urinary sodium assessed for an unspecified subset of total population
Japan (1985–99)	Liu *et al.*[129]	Random population samples from eight locations throughout Japan	48–56 yr	Single 24-h urine collection	484 men 542 women	221.2 ± 92.4 194.5 ± 72.2	Individuals with incomplete urine collections, or prescribed drug treatment for hypertension were excluded
Japan (1993–94)	Kawamura *et al.*[130]	Non-random sample of healthy long-term residents of the Moriokia Iwate area	30–65 yr	Single 24-h urine collection	132 men 70 women	231 ± 78 189 ± 78	Known to be an area of high salt consumption
Japan (1996–98)	Stamler *et al.*[29]	Age–sex stratified random samples from three urban occupational populations and one semi-rural community, INTERMAP Study	40–59 yr	Two 24-h urine collections with an average of 3 weeks between collections	574 men 571 women	210.5 ± 56.6 186.0 ± 53.1	
Netherlands (n/a)	Geleijnse *et al.*[131]	Non-random sample. All age-eligible residents of a suburb of Rotterdam were invited to participate	>55 yr	Single overnight urine collection	1006 men and women: Men Women	 137.0 ± 66.0 103.0 ± 50.0	

(continued)

Table 1 Continued

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
Nigeria (1991–94)	Cooper *et al.*[64]	Random sample of the general population in rural and urban areas	⩾25 yr	Single 24-h urine collection	2509 men and women	121.5 ± 76.1	Urinary sodium assessed for an unspecified subset of total population
Nigeria (1994)	Kaufman *et al.*[132]	Random recruitment of 'rural farmers' and 'urban poor' who had participated in an earlier study, and of age-eligible members of the Nigerian Railway Pensioners' Union	>45 yr	Single 24-h urine collection	144 men 178 women	111.6 ± 53.6 108.8 ± 60.0	
Panama (n/a)	Hollenberg *et al.*[39]	Non-random samples of Kuna Indians from the isolated San Blas Islands. All participants were from the same nine families	18–82 yr	Single 24-h dietary recall	50 men and women	210.0 ± 155.6	
People's Republic of China (1985–99)	Liu *et al.*[133]	Random population samples from 11 locations throughout China	48–56 yr	Single 24-h urine collection	572 men 563 women	205.1 ± 84.8 175.4 ± 83.9	
People's Republic of China (1985–2000)	Liu *et al.*[70]	Random samples of men and women from Han, Uygur, Kazak and Tibetan ethnic populations	48–56 yr	Single 24-h urine collection	775 Han 510 Uygur 204 Kazaks 125 Tibetans	193.0 ± 97.4 173.5 ± 135.5 213.1 ± 137.1 253.7 ± 114.0	Approximately even number of men and women Individuals with incomplete urine collections, or prescribed drug treatment for hypertension were excluded (included in given n)
People's Republic of China (1992)	Nan *et al.*[71]	Random sample of the general population from an urban area of Tianjin	15–64 yr	3-day weighed food record	1133 men 1184 women	283.3 ± 109.7 248.2 ± 96.6	
People's Republic of China (1995–96)	Woo *et al.*[134]	Age–sex stratified random sample of the Hong Kong Chinese population	25–74 yr	266-item FFQ	500 men 510 women	210.5 ± n/a 196.4 ± n/a	Individuals with incomplete urine collections, prescribed drug treatment for hypertension excluded
People's Republic of China (1997–98)	Stamler *et al.*[29]	Age–sex stratified random samples from three rural communities (two northern and one southern China), INTERMAP Study	40–59 yr	Two 24-h urine collections with an average of 3 weeks between collections	276 northern men 285 northern women 140 southern men 138 southern women	293.2 ± 91.8 250.2 ± 77.3 149.7 ± 58.9 128.1 ± 52.9	
South Africa (n/a)	Charlton *et al.*[135]	Individuals recruited from Cape Town City Council	20–65 yr	Three 24-h urine collections over a 3-week period	110 black 112 mixed ancestry 103 white	135.3 ± 50.1 147.5 ± 73.5 164.8 ± 91.0	Approximately even number of men and women
Spain (1994–96)	Schroder *et al.*[66]	Random sample of Gerona province population, stratified by age and sex	25–74 yr	72-h dietary recall	986 normotensive 371 non-medicated hypertensive 210 medicated hypertensive	93.1 ± n/a 96.3 ± n/a 91.9 ± n/a	Means are age, sex, energy adjusted

(continued)

Table 1 Continued

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
St. Lucia (1991–94)	Cooper *et al.*[64]	Random sample of general population from periurban areas, including Vieux Forte	≥25 yr	Single 24-h urine collection	1089 men and women	145.9 ± 62.5	Urinary sodium assessed for an unspecified subset of total population
Taiwan (1990)	Liu and Chung[67]	Non-random sample of students, faculty and staff of the National Tsing Hua University	n/a	Chemical analysis of 3-day duplicate food portions	8 men 7 women	109.6 ± 113.0 98.3 ± 52.2	
Tanzania and Uganda (n/a)	Pavan *et al.*[68]	Non-random general population sample of Lugarawa and Lugbara districts, stratified by age and sex	22–89 yr	Unspecified dietary method	370 men and women	68.5 ± n/a	
UK (1993–97)	Khaw *et al.*[61]	Non-random sub-sample of the EPIC-Norfolk cohort	45–79 yr	Six 24-h urine collections over one year	159 men 181 women	161.0 ± 64.0 125.0 ± 42.0	
UK (1997–99)	Stamler *et al.*[29]	Age–sex stratified random samples from two areas, a combination of occupational and community sampling, INTERMAP Study	40–59 yr	Two 24-h urine collections with an average of 3 weeks between collections	266 men 235 women	160.9 ± 51.3 127.4 ± 39.7	
UK (2000–01)	Henderson *et al.*[136]	Nationally representative sample, NDNS	19–64 yr	Single 24-h urine collection	567 men 580 women	187.4 ± 85.8 138.5 ± 66.4	
UK (2005–06)	National Centre for Social Research[76]	Nationally representative sample	19–64 yr	Single 24-h urine collection with PABA tablets	294 men 398 women	166 ± 70 131 ± 50	
USA (1996–98)	Stamler *et al.*[29]	Age–sex stratified random samples from eight areas, a combination of occupational and community sampling, INTERMAP Study	40–59 yr	Two 24-h urine collections with an average of 3 weeks between collections	1103 men 1092 women	182.7 ± 62.4 142.3 ± 48.3	
USA (1999–2000)	Wright *et al.*[137]	Nationally representative sample (excluding nursing infants), NHANES 1999–2000	All ages (children and adults)	Single 24-h dietary recall	4206 males 4398 females	168.6 ± 170.6 125.9 ± 115.0	
Venezuela (n/a)	Negretti de Bratter *et al.*[69]	Individuals recruited for a case–control study in high- and low-altitude areas of the state of Tachira	n/a	Chemical analysis of one day duplicate food portions	77 high altitude 33 low altitude	90.5 ± n/a 64.0 ± n/a	

[a]Converted to mmol/day by: sodium (mg/1000 kcal) × [energy intake (kcal)]/1000].
[b]Converted to mmol/day by: [sodium (mmol)/12 h] × 24 h.
[c]Standard deviation estimated by: [(Upper 95% confidence interval – mean)/1.96] × √sample size.
Sodium: 1 mmol = 23 mg.
EPIC, European Prospective Investigation into Cancer and Nutrition; FFQ, Food Frequency Questionnaire; INTERMAP, International Study of Macro- and Micro-Nutrients and Blood Pressure; n/a, not available; NDNS, National Diet and Nutrition Survey; NHANES, National Health and Nutrition Examination Survey; PABA, para-aminobenzoic acid; SD, standard deviation; yr, years.

western countries, the standard deviation of urinary sodium is inflated so that even fewer people had 'true' (average, long-term) urinary sodium excretion below these values.[62]

Other studies published since 1988

Table 1 lists studies published since 1988, giving data on sodium intake or urinary excretion from different countries around the world. It includes 28 reports from 25 countries on six continents. Intakes of <100 mmol/day were reported in American and Western Samoa,[63] Cameroon,[64] Ghana,[65] Spain,[66] Taiwan,[67] Tanzania and Uganda[68] and Venezuela,[69] but these reports were based on a variety of methods including dietary recall, unspecified questionnaire and duplicate diets, and only two relied on 24-h urine collections[64,65]—the validity of the other estimates is therefore open to question. Studies in PRC gave sodium intake estimates ranging from 174 mmol/day for men and women from an ethnic Uygur population[70] to 254 mmol/day in men from urban Tianjin.[71] Across all countries, in all studies with gender-specific data, mean sodium intakes in men were higher than in women, largely reflecting differences in total food consumption.

Time trends

As a result of public health campaigns in Japan to lower sodium intake,[21] the very high sodium intakes recorded in northern Japan in the 1950s and early 1960s were not observed in the INTERSALT[8] and INTERMAP studies, nor other recent surveys (Table 1). Data from the Japanese National Nutrition Survey show a fall in mean daily sodium intake from 248 mmol/day in 1973 to 200 mmol/day in 1987. Since 1987 sodium intakes in Japan appear to have levelled off or even risen, though changes in survey technique and in total energy intake complicate interpretation of the later data.[72] Prospective INTERSALT data are consistent with the levelling off observed in the National Nutrition Survey in Japan: among INTERSALT participants examined in 1985 and followed up 8 years later in 1993, sodium excretion was hardly changed, except in Toyama, where a small decrease was noted (significant only in women aged 20–39 years).[73]

In Belgium, where the amount of sodium in bread was reduced from the mid-1960s to the early 1980s,[22] mean daily sodium excretion has declined over the same period: from 265 to 188 mmol/day in men ages $\geqslant$65 years, and from 208 to 160 mmol/day in women ages $\geqslant$60 years.[74] In Finland—subject to a concerted public health effort to reduce cardiovascular disease (CVD) risk—marked reductions in sodium excretion were documented from 1979 to 2002: annual decrease in men of 2.4 mmol/day, in women 1.9 mmol/day (both $P < 0.001$).

In the UK, there was a small increase in mean 24-h urinary sodium excretion between national surveys conducted in 1986 and 2000 (from 173 to 187 mmol/day in men, $P < 0.05$; from 132 to 138 mmol/day in women, P non-significant);[75] while nationally representative data collected in 2005 indicate a reduction of sodium intakes in both men and women to 166 and 131 mmol/day, respectively.[76]

In the USA, the NHANES national surveys reported successively higher sodium intakes in consecutive surveys from 1971 to 1994, while the Continuing Survey of Food Intakes by Individuals (CSFII) reported unchanged or higher sodium intakes from 1985 to 1996. It is not clear to what extent these increases might reflect methodological changes in the surveys.[77] Four market-research panel surveys of USA adults conducted between 1980 and 1992, based on 14-day food diaries, recorded little change in mean sodium intake.[25]

Sodium intakes in children and adolescents

Fewer data are available on sodium intake in children and young people than in adults, and these are mainly limited to the developed nations of Europe and North America.[33,34] We focus here on observational and interventional studies identified by systematic literature review, and on recent reviews of observational studies of diet and BP in children[34] and of dietary surveys among European children,[33] comprising in total 41 reports from 20 countries on four continents (Table 2).

Highest mean dietary sodium intake was reported for Danish boys (14–19 years), mean intake 191 mmol/day,[78] and Chinese boys and girls (12–16 years) from rural Shanxi, mean intake 174.4 mmol/day.[79] Dietary intake was >140 mmol/day among boys from Belgium, Hungary, Netherlands, Spain, USA[80–84] and black boys and girls from Chicago and Tennessee, USA.[84,85]

Among children $\leqslant$5 years old, sodium intake was consistently <100 mmol/day, ranging from 72 mmol/day in British children aged 4 months[86] to 88.9 mmol/day in American children aged 3–5 years.[87] Intakes <100 mmol/day were also reported in some older children, including boys aged 8–9 years from Belgium, Bulgaria, Finland, Netherlands and Sweden;[81] Polish boys (but not girls) aged 9–11 years;[88] Dutch boys and girls aged 15 years;[89] Greek girls aged 13–14 years;[90] Swedish girls aged 14–17 years;[91,92] and American girls aged 11–19 years.[93,94] When interpreting these apparently favourable intakes, the potential for underestimation of sodium intake by both dietary and urinary survey methods—particularly problematic in children—needs to be considered.

Where comparable data were available, sodium intake tended to be higher among boys than girls by ~20 mmol/day on average. Reports from Italy and Poland were exceptions: mean intakes were higher among girls than boys by ~4 and 30 mmol/day, respectively.[88,95] Mean sodium intake appeared to increase with age. Based on all dietary and urinary data included in Table 2, regression of mean sodium on age indicated sodium intake higher by ~4.3 mmol/day per year of age. Observed trends by age and sex

Table 2 Mean dietary intake or urinary excretion of sodium for children and adolescents from around the world: 1968–present

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
Australia (1985)	Jenner *et al.*[138]	Representative random sample of Perth school children	9 yr	160-item FFQ	434 boys 450 girls	114.8 ± 30.9 104.8 ± 30.9	
Austria (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Vienna	8–9 yr	Single 24-h urine collection	43 boys	106.0 ± 41.3	
Belgium (1979–81)	Staessen *et al.*[80]	Random population sample from two towns	10–19 yr	Single 24-h urine collection	82 boys 78 girls	142.0 ± 64.0 129.0 ± 48.0	
Belgium (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Ghent	8–9 yr	Single 24-h urine collection	38 boys	92.0 ± 38.2	
Bulgaria (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Sofia	8–9 yr	Single 24-h urine collection	58 boys	93.0 ± 32.8	
Denmark (1995)	Lyhne[78,a]	National	14–19 yr	7-day diet diary	116 boys 129 girls	191.3 ± 69.6 134.8 ± 43.5	
Denmark (1997–98)	Hoppe *et al.*[139]	Random sample of children born at a hospital in Hvidovre	10 yr	7-day diet diary	51 boys 54 girls	154.9 ± 41.6 128.7 ± 34.3	
Finland (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Turku	8–9 yr	Single 24-h urine collection	48 boys	94.0 ± 36.0	
Finland (1990–97)	Heino *et al.*[140]	Non-random sample of boys and girls recruited from well-baby clinics in Turku	1–5 yr	3-day weighed food record at 13 mo, 4-day weighed record at 3 and 5 yr	100 boys: 13 mo 3 yr 5 yr 100 girls: 13 mo 3 yr 5 yr	 70.0 ± 23.4 84.4 ± 23.4 100.0 ± 24.2 68.3 ± 22.5 82.6 ± 20.3 94.0 ± 21.6	
Finland (1997–98)	Rasanen *et al.*[141]	Non-random sample of children from the control group of the Special Turku Coronary Risk Factor Intervention Project	7 yr	4-day weighed food record	40 boys and 30 girls	106.1 ± 21.7	
Germany (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in three areas	8–9 yr	Single 24-h urine collection	Berlin: 44 boys Freiburg: 46 boys Heidelberg: 40 boys	103.0 ± 63.0 127.0 ± 54.9 106.0 ± 36.0	
Germany (1998)	Deutsche Gesellschaft fur Ernahrung eV[142,a]	National	14–19 yr	1-day weighed record and diet history	38 924 boys and girls	139.1 ± n/a	
Germany (1996–2003)	Remer *et al.*[143]	Non-random sample of children participating in the DONALD study	6–12 yr	Single 24-h urine collection	178 boys 180 girls	136.0 ± 51.3 117.3 ± 46.9	

(continued)

Table 2 Continued

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
Greece (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Athens	8–9 yr	Single 24-h urine collection	50 boys	112.0 ± 43.1	
Greece (1987–88)	Hassapidou *et al.*[90,a]	Local	13–14 yr	3-day weighed record	20 boys and girls: Boys Girls	 105.9 ± 42.7 78.1 ± 36.8	
Hungary (1986)	Knuiman *et al.*[81]	Two random sample of boys from selected schools in Budapest	8–9 yr	Single 24-h urine collection	46 boys 27 boys	146.0 ± 57.0 138.0 ± 40.0	
India (n/a)	Joshi *et al.*[144]	Non-random sample of children recruited from families attending a hospital in Mumbai	2–18 yr	Single 24-h urine collection	Family history of hypertension: 90 No family history of hypertension: 25	99.9 ± 23.4 86.7 ± 27.0	Groups were age-matched
Italy (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in three areas	8–9 yr	Single 24-h urine collection	Catania: 45 boys Milan: 48 boys Rome: 45 boys	131.0 ± 48.3 115.0 ± 40.2 114.0 ± 40.2	
Italy (1988)	Agostoni *et al.*[95,a]	Sample of boys and girls from the town of Corsico	11 yr	Single 24-h dietary recall	55 boys 65 girls	138.0 ± 35.0 142.0 ± 46.0	
Japan (n/a)	Yamauchi *et al.*[145]	Non-random sample from city of Nagoya	6–11 yr	7-day diet diary	169 boys and 153 girls	128.4 ± 45.7	
Netherlands (1975–78)	Geleijnse *et al.*[82]	Random sub-sample of population study of a suburban town in western Netherlands	5–17 yr	more then 6 overnight urine collections	108 boys 125 girls	140.8 ± n/a 131.1 ± n/a	
Netherlands (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Wageningen	8–9 yr	Single 24-h urine collection	43 boys	91.0 ± 32.8	
Netherlands (1995)	Geleijnse *et al.*[89]	Non-random sample of children born to mothers in Zoetermeer in 1980, assigned to either normal or low sodium diet at birth for 6 mo	15 yr	Single overnight urine collection	Normal diet: 48 boys and 48 girls Low sodium diet: 38 boys and 33 girls	85.0 ± 46.0 75.0 ± 31.0	
Netherlands (1993–2005)	Schreuder *et al.*[146]	Non-random sample of children attending a medical centre in Amsterdam	5–10 yr	Single 24-h urine collection	1993–95: 45 children 2003–05: 142 children	65.0 ± 39.0 101.0 ± 59.0	Mean weight was higher in the latter group
People's Republic of China (1985)	Zhu *et al.*[147]	Non-random sample of boys from two schools in Wuhan	7–8 yr	Seven 24-h urine collections	148 boys	128.8 ± 35.9	
People's Republic of China (n/a)	Wu *et al.*[79]	Non-random sample from rural area of Shaanxi	12–16 yr	Three consecutive 24-h urine collections	94 boys and 87 girls	174.4 ± 63.3	

(continued)

Table 2 Continued

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
Poland (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Warsaw	8–9 yr	Single 24-h urine collection	60 boys	101.0 ± 38.7	
Poland (1996–98)	Hamulka and Gronowska-Senger[88,a]	Regional	9–11 yr	Single 24-h dietary recall and FFQ	224 boys and girls: Boys Girls	 84.8 ± 25.2 114.7 ± 32.6	
Portugal (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Lisbon	8–9 yr	Single 24-h urine collection	52 boys	128.0 ± 43.3	
Spain (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Madrid and Santiago	8–9 yr	Single 24-h urine collection	Madrid: 57 boys Santiago: 57 boys	122.0 ± 40.0 127.0 ± 40.0	
Spain (1993–94)	Maldonado-Martin *et al.*[83]	Random sample of children from public primary schools in the Almeria province	6–14 yr	Single 24-h urine collection	274 boys 279 girls	142.2 ± 70.4 125.6 ± 53.5	
Sweden (1986)	Knuiman *et al.*[81]	Random sample of boys from selected schools in Lund	8–9 yr	Single 24-h urine collection	40 boys	97.0 ± 32.9	
Sweden (1989–90)	Bergstrom *et al.*[91,a]	Non-random sample of boys and girls from four schools in the city of Umea	14 and 17 yr	7-day diet diary	14 yr: 155 boys 14 yr: 189 girls 17 yr: 211 boys 17 yr: 176 girls	130.7 ± 36.6 96.8 ± 23.4 152.1 ± 39.6 97.7 ± 28.3	
Sweden (1993–94)	Samuelson *et al.*[92,a]	Random sample of boys and girls from Uppsala and Trollhattan	15 yr	7-day diet diary	Uppsala: 99 boys Uppsala: 104 girls Trollhattan: 85 boys Trollhatan: 110 girls	155.3 ± 41.9 117.1 ± 26.8 143.0 ± 33.5 99.0 ± 23.7	
UK (1992–93)	Gregory *et al.*[148,a]	Nationally representative sample, NDNS	1.5–4.5 yr	4-day weighed record	848 boys 827 girls	66.6 ± 20.3 64.3 ± 20.6	
UK (1992–93)	Brion *et al.*[86]	Random sub-sample of children enrolled in the ALSPAC cohort, Avon	4 mo 8 mo	1-day diet diary 3-day diet diary	533 boys and girls 710 boys and girls	7.2 ± 2.1[b] 23.1 ± 12.3[b]	
UK (1997)	Gregory and Lowe [38,a]	Nationally representative sample, NDNS	4–18 yr	7-day weighed record	856 boys 845 girls	114.3 ± 36.0 93.7 ± 25.2	
USA (1968–70)	Watson *et al.*[96]	Random sample stratified by race of black and white girls from schools in Hinds county, MS	14–18 yr	One-to-six 24-h urine collections	356 black girls 104 white girls	112.8 ± 48.0 98.4 ± 50.4	
USA (1973–88)	Nicklas[149]	Non-random sample of children from Bogalusa, LA, for the Bogalusa Heart Study	10 yr	Single 24-h dietary recall	1973–74: 185 1976–77: 158 1978–79: 224 1981–82: 304 1984–85: 284 1987–88: 284	144.8 ± n/a 148.4 ± n/a 158.8 ± n/a 155.5 ± n/a 154.8 ± n/a 163.8 ± n/a	Study population 65% white, 50% female

(continued)

Table 2 Continued

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
USA (n/a)	Cooper *et al.*[84]	Non-random sample of black and white children from two Chicago, MI schools	11–14 yr	Seven 24-h urine collections	45 black children 28 white children 31 boys 42 girls	140.0 ± 47.3 121.1 ± 34.3 149.2 ± 46.0 120.6 ± 37.6	Black children one school year older than white children
USA (n/a)	Ellison *et al.*[93]	Non-random sample of participants from the Collaborative Perinatal Study cohort, Boston, MA	16–17 yr	Three overnight urine samples	130 boys 118 girls	113.2 ± n/a[c] 80.3 ± n/a[c]	Mean collection period 9.2 hours
USA (n/a)	Faust *et al.*[150]	Non-random sample of residents from a rural area of Michigan	<18 yr	Three overnight urines combined to give 24-h estimate	36 boys and girls	103.9 ± 69.2	
USA (n/a)	Cooper *et al.*[151]	Non-random sample of black children from five Chicago, MI schools	11–14 yr	Seven 24-h urine collections	Three schools: 97 children Two schools: 72 children	126.8 ± 36.9 107.2 ± 35.5	
USA (1978–79)	Connor *et al.*[152]	Random sample of households in a suburb of Portland, OR	6–15 yr	Single 24-h urine collection	115 boys and girls	102.0 ± 54.0	
USA (1984)	Witschi *et al.*[153]	Non-random sample of children from two boarding high schools in Exeter, NH and Andover, MA	n/a	Single 1-day food diary	108 boys 92 girls	170.0 ± 64.0 109.7 ± 47.0	High school implies children aged 14–17 yr
USA (n/a)	Sanjur *et al.*[154]	Non-random sample of low-income families visiting two healthcare centres in Denver, CO	1–2 yr	3-day diet diary	90 boys and girls	58.4 ± 22.0	Families were mainly Hispanic Discretionary salt use was not recorded
USA (n/a)	Harshfield *et al.*[85]	Non-random sample of black and white children recruited from churches, schools and social organisations in Tennessee	10–18 yr	Single 24-h urine collection	66 black children 74 white children	144.4 ± 48.0 129.4 ± 54.0	
USA (n/a)	Gillman *et al.*[87]	Non-random sample of children: The Framingham Children's Study	3–5 yr	Four 3-day diet diaries over a one yr period	89 boys and girls	88.9 ± 19.2	Uneven number of boys ($n = 55$) and girls ($n = 34$)
USA (1987-1999)	Simon *et al.*[97]	Non-random sample of girls from schools in Richmond, CA and Cincinnati, OH. A random age–race stratified sample from families of the Group Health Association, Washington, DC	9–10 yr	3-day diet diary	987 black girls 1043 white girls	133.6 ± 46.6 121.9 ± 36.2	

(continued)

Table 2 Continued

Country (survey year)	References	Sampling	Age range	Measurement	Sample size	Mean sodium ±SD, mmol/day	Notes
USA (1991–97)	Lytle *et al.*[98]	Non-random sample of children recruited for the CATCH trial, from schools in CA, LA, MN and TX	8–14 yr	24-h dietary recall at school grades 3, 5 and 8	Grade 3:		
					226 black	132.8 ± 43.8	
					284 Hispanic	132.7 ± 45.4	
					1297 white	135.2 ± 47.0	
					Grade 5:		
					145 black	133.4 ± 42.9	
					209 Hispanic	136.4 ± 44.6	
					958 white	136.3 ± 45.8	
					Grade 8:		
					183 black	138.6 ± 43.5	
					215 Hispanic	141.4 ± 44.0	
					1043 white	141.2 ± 46.3	
USA (1998)	Gilliland *et al.*[94]	Non-random sample of children enrolled in schools participating in Children's Health Study, within 200km radius of Los Angeles, CA	11–19 yr	FFQ	1177 boys:		
					11–14 yr	109.5 ± 48.3	
					15–16 yr:	103.6 ± 42.9	
					17–19 yr:	112.4 ± 44.2	
					1389 girls:		
					11–14 yr:	99.4 ± 44.7	
					15–16 yr:	95.3 ± 40.3	
					17–19 yr:	98.6 ± 40.0	
USA (n/a)	Zive *et al.*[155]	Non-random sample of children recruited for the Study of Children's Activity and Nutrition from 63 schools and children's centres	4–12 yr	Two 24-h recalls (with mealtime observation for ages 4–7 yr) at baseline, 6, 12, 18, 24, 30, 78 and 84 mo	Baseline to 30 mo: 207	80.5 ± 2.0	Top SD appears to be a typographical error
					78–84 mo: 228	147.6 ± 45.7	
USA (1999–2000)	Wright *et al.*[137]	Nationally representative sample (excluding nursing infants), NHANES 1999–2000	0–19 yr	Single 24-h dietary recall	Boys		
					<6 yr: 628	96.7 ± 78.3	
					6 to 11 yr: 494	152.2 ± 209.8	
					12 to 19 yr: 1105	183.2 ± 181.8	
					Girls		
					<6 yr: 567	86.7 ± 74.1	
					6–11 yr: 468	130.1 ± 92.8	
					12–19 yr: 1103	132.2 ± 130.1	
USA (2002)	Heird *et al.*[156]	National random sample of children	4–24 mo	Single 24-h dietary recall	4–5 mo: 624	8.2 ± n/a	
					6–11 mo: 1395	21.4 ± n/a	
					12–24 mo: 1003	71.2 ± n/a	

[a]Source: Lambert *et al.*[33]

[b]Standard deviation estimated by: 0.7413 × inter-quartile range, assuming normal distribution.

[c]Converted to mmol/day by: [sodium (mmol)/9.2 h] × 24 h.

Sodium: 1 mmol = 23 mg.

ALSPAC, Avon Longitudinal Study of Parents and Children; CATCH, Child and Adolescent Trial for Cardiovascular Health; DONALD, Dortmund Nutritional and Anthropometric Longitudinally Designed Study; FFQ, food frequency questionnaire; mo, months; n/a, not available; NDNS, National Diet and Nutrition Survey; NHANES, National Health and Nutrition Examination Survey; SD, standard deviation; yr, years.

are likely to reflect differences in total food consumption as well as differences in food choices: the greater energy requirement in older compared with younger children, and in males compared with females, leads to greater sodium consumption, independent of food choice.

Estimates from four US studies indicate that black children consume and excrete more sodium than their white peers.[84,85,96,97] Among these studies, mean sodium intake was ~15 mmol/day higher in black than white children. One study, however, found no significant differences between black, white and Hispanic children aged 8–14, based on 24-h recalls collected prospectively in school grades 3, 5 and 7.[98]

Food sources of sodium

Adults

In European and Northern American diets, an estimated 75% of sodium intake comes from processed or restaurant-prepared foods; 10–12% occurs naturally in foods; and a similar proportion is from discretionary use at home or at the table.[26,27] Table 3 lists the differences in salt content between processed and unprocessed varieties for selected common foods; tinned salmon, for example, contains five times the sodium content of fresh steamed salmon, while smoked salmon contains 16 times as much. The point is further illustrated in Figure 1, which presents home-cooked and ready-meal versions of two popular dishes, along with their respective sodium content. According to UK National Food Survey data collected in 2000, cereal products (including bread, other baked goods and breakfast cereals) accounted for the greatest proportion (38%) of household sodium intake. The second largest source (21%) was meat products (including processed meats such as ham, bacon, etc.), though salt added at the table or consumed away from home was not measured.[99] Data from the USA CSFII (1994–96) show a similar pattern: cereals and baked goods providing >16% sodium; meat products >13%. Estimates did not include salt from disaggregated multi-component foods, or certain meat products including hot dogs and bacon—both high sodium foods.[100]

A different picture with regard to dietary sources of sodium is apparent for some Asian countries. In PRC and Japan, the greatest proportion of dietary sodium comes from salt added during cooking and sauces, including soy sauce and (in Japan) miso. In the Chinese Health and Nutrition Survey 2002, 72% of sodium was from salt added during cooking and 8% from soy sauce (Table 4).[101] Unpublished INTERMAP data reflect closely these survey data for PRC: main sources were salt added in home cooking or at the table (76%) and soy sauce (6.4%); in Japan main sources were soy sauce (20%), salted vegetables and fruits (9.8%), miso soup (9.7%), fresh and salted fish (9.5%) and salt added in restaurants, fast food and at home (9.5%).[102]

Table 3 Comparing the sodium content of unprocessed and processed foods[100]

Food item	Description	Sodium content (mmol/100 g)
Beef	Topside, roast, lean and fat	2.1
	Corned beef, canned	41.3
Bran	Bran, wheat	1.2
	Bran flakes	43.5
Cheese	Hard cheese, average	27.0
	Processed cheese	57.4
Chick peas	Dried, boiled in unsalted water	0.2
	Canned, re-heated, drained	9.6
Crab	Boiled	16.1
	Canned	23.6
Cod	Cod, in batter, fried in blended oil	4.3
	Fish fingers, fried in blended oil	15.2
New potatoes	Raw, boiled in unsalted water	0.4
	Canned, re-heated, drained	10.9
Peanuts	Plain	0.1
	Dry roasted	34.3
	Roasted and salted	17.4
Peas	Raw, boiled in unsalted water	Trace
	Canned, re-heated, drained	10.9
Potato chips (fries)	Homemade, fried in blended oil	0.5
	Oven chips, frozen, baked	2.3
Salmon	Raw, steamed	4.8
	Canned	24.8
	Smoked	81.7
Sweet corn	On-the-cob, whole, boiled in unsalted water	Trace
	Kernels, canned, re-heated, drained	11.7
Tuna	Raw	2.0
	Canned in oil, drained	12.6
	Canned in brine, drained	13.9

Sodium: 1 mmol = 23 mg.

Children

Data on food sources of sodium are limited. In UK children and adolescents aged 4–18 years, surveyed for the UK Diet and Nutrition Survey 1992, major sources of sodium reflect those for adults: cereals contribute 38–40%, meat products 20–24%.[103]

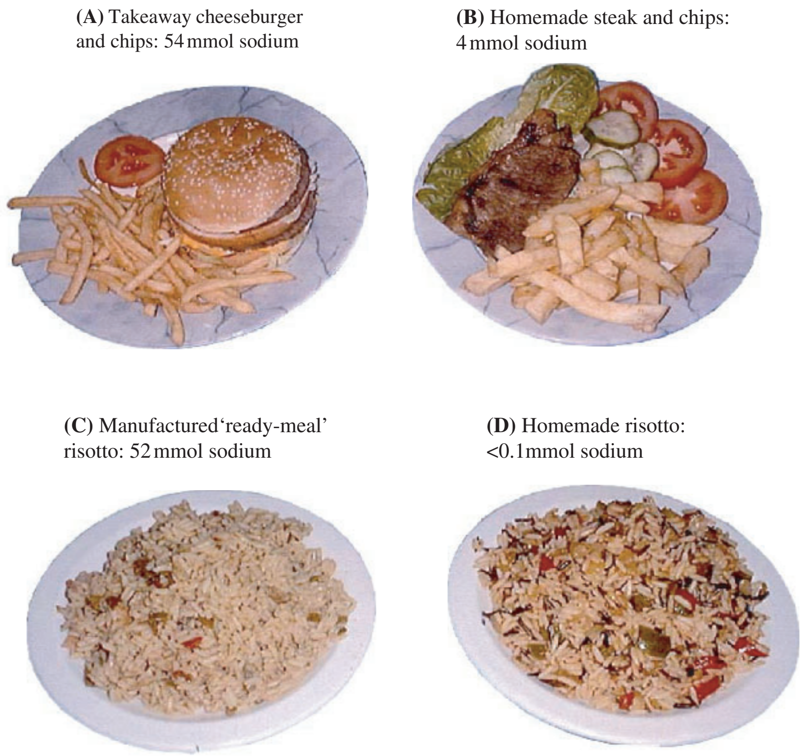

Figure 1 The sodium content of manufactured (**A,C**) and homemade (**B,D**) meals
Sodium: 1 mmol = 23 mg

Table 4 Mean intake of sodium, overall, by source and by area, for the participants of China Health and Nutrition Survey, 2002[a,101]

Area	Total sodium[b] mmol/day	Sodium from cooking salt mmol/day (%)	Sodium from soy sauce mmol/day (%)	Sodium from other seasonings mmol/day (%)	Sodium from other sources mmol/day (%)
Urban	261.2	174.0 (66.6)	26.4 (10.1)	9.7 (3.7)	51.2 (19.6)
Rural	276.9	205.5 (74.2)	20.8 (7.5)	8.9 (3.2)	41.8 (15.1)
Overall	272.5	196.5 (72.1)	22.3 (8.2)	9.0 (3.3)	44.4 (16.3)

[a]A multi-stage, random cluster method was used to select ~15 000 individuals, aged ⩾2 years and over, from nine provinces.
[b]Sodium intake was estimated from 3-day weighed food records (2 work days and 1 rest day).
Sodium: 1 mmol = 23 mg.

Among US girls who reported that they ate fast food at least four times a week, sodium intake was higher than among girls who ate fast food less than once a week (mean 140.7 vs 134.1 mmol/day, $P < 0.001$).

Discussion

Sodium intakes of different populations around the world vary markedly. The report of a joint WHO/FAO Expert Consultation on 'Diet, Nutrition and the Prevention of Chronic Diseases' recommends that sodium intake of adults should be <85 mmol/day (2 g/d).[104] In the vast majority of populations, salt intake is high and well above recommended daily intakes. High intakes, which tend to increase with age, are also reported among children and young adults.

There is strong and consistent evidence from animal studies, clinical trials and epidemiological data both within and across populations implicating high salt intake as an important risk factor for high BP among both hypertensive and normotensive individuals;[2–8] high salt intake is also associated with increased risk of future CHD and stroke.[9–12] Nonetheless, most adult populations have mean sodium intakes well in excess of 100 mmol/day (2.30 g/d), and in many (especially the Asian countries) in excess of 200 mmol/day (4.60 g/day)—three times the current US guideline amount for middle-aged and older adults (65 mmol/day, 1.5 g/day).[105] Salt has historically been used as a method of food preservation; however, with the introduction in the 20th century of the modern refrigerator in many countries, this need has been reduced. While extremely high intakes reported in the late 1950s and the early 1960s in some countries, notably northern Japan, are no longer apparent, there is evidence to suggest that in some countries sodium intake may be on the rise.[73] At the same time, few countries have policies for targeted reductions in salt intake.

There are differences between developed and developing countries with regard to dietary sources of salt. In European and Northern American diets, a large proportion of the sodium ingested (as high as 75% in USA and UK) is added (as sodium chloride) in food manufacture and foods eaten away from the home.[26,27] Therefore, sodium is often 'hidden' in foods and individuals are unaware of the amount of salt they consume. Personal efforts to reduce salt intake may be hampered by the large quantities of salt found in processed foods: unpublished INTERMAP data show that for individuals who made a conscious effort to reduce salt intake compared to others, sodium excretion was greatly reduced only among the rural PRC samples (by 55.9 mmol/day, $P < 0.05$); smaller decreases were observed for Japanese and Americans (18.9 and 13.6 mmol/day, respectively, both $P < 0.05$); no difference was seen for UK participants (Okuda, N., personal communication). Therefore, public health initiatives to limit salt consumption can only be effective in tandem with government/industry initiatives to reduce the salt content of processed foods.[106,107]

In Finland, which has been subject to a comprehensive public health campaign in collaboration with the food industry to reduce CVD, marked reductions in salt intake were documented over a 20-year period, which coincided with a decrease of ~60% in both CHD and stroke mortality.[24,108] Since 2004 the UK Food Standards Agency has addressed sodium reduction concomitantly on two fronts: a media campaign (originally featuring on a hapless cartoon slug named 'Sid') to increase public awareness;[109] and voluntary salt reduction targets for 85 categories of processed foods for the food industry. As a result, major retailers, manufacturers, caterers and trade associations are reporting reductions in the sodium content of a wide variety of processed foods;[110] and recent population survey data indicate that UK sodium intakes are falling.[76] Similar public health approaches are needed in other developed countries to limit the amount of salt consumed and consequently decrease the burden of cardiovascular morbidity and mortality worldwide. Research has shown that lower sodium concentration in foods can be readily achieved; one-quarter reduction in the sodium content of sliced white bread can be delivered largely unnoticed in the population.[111]

In 2000, ~7.1 million deaths worldwide were attributed to non-optimal BP.[112,113] Lowering the salt intake of individuals around the world is expected to shift the population distribution of BP towards more optimal levels, thus preventing thousands of deaths from CVD and stroke, and reducing the burden on overstretched health services. In the UK, for example, it was estimated that a population-wide reduction in sodium intake of 100 mmol/day would lead to mean systolic and diastolic BP falls of 5.0 and 2.8 mm Hg, preventing nearly 22 000 deaths from CHD and 15 000 deaths from stroke.[114] Sodium reduction is one of the easiest to implement, cost-effective and efficient ways to reduce the global burden of CVD and thus should not be overlooked.[115]

A different picture with regard to dietary sources of sodium is apparent in some developing countries, where sodium in the diet comes mainly from salt added during cooking and from sauces (e.g. soy sauce in China). These countries are amid an epidemiological transition with increasing rates of chronic diseases including hypertension and CVD.[116,117] There is therefore the opportunity for timely community-based, context-specific initiatives to limit the amount of salt added to food by individuals.[36] It is also essential, given the increasing westernization of these cultures, to encourage low levels of salt content in processed foods, which are likely to become increasingly available in the developing world. Such initiatives are needed to tackle the forecasted epidemic of CVD in developing countries.

Data on sodium intakes of children and young people are limited. Data presented here show high intakes even at young ages and a trend of sodium intake to increase with age. Higher intake in infancy has been linked with higher BP later in life.[86,89] Modest reductions in salt intake in childhood could help stem the rise in BP observed with age and prevent future CVD events.[8] Salt intake has recently been proposed as a major determinant of sugar-sweetened soft-drink consumption in children,[118] which in turn has been related to childhood obesity—an independent risk factor for high BP and CVD.[119] Further studies are needed to provide contemporaneous, valid information on sodium intake in young populations around the world, as current data have limited validity and comparability.

Detection and treatment of hypertension is a major component of cardiovascular risk reduction. However, the underlying causes of hypertension, such as poor diet, are often left 'untreated'. Patients with drug-treated hypertension are at higher risk of CVD than individuals with normal BP.[120,121] Similarly, amongst drug-treated hypertensives, those with unhealthy lifestyle are at a higher risk of CVD than those with healthy lifestyle.[120,121] There is also evidence that reduced salt intake in treated individuals may reduce the number and dose of drugs or obviate the need for treatment.[122–124] Our review shows that in the vast majority of populations salt intake is well above the recommended levels. Public health initiatives, in tandem with efforts by the food industry, are urgently needed to lower salt consumption and consequently lower CVD burden and increase life expectancy. Such public health approaches can be simple, low-cost and effective.

Supplementary data

Supplementary data are available at *IJE* online.

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Conflicts of interest: WHO commissioned a background paper on 'Salt intakes around the world' from PE and IJB, presented during the WHO Forum and Technical Meeting on Reducing Salt Intakes in Populations (2006). PE is a member of CASH (Consensus Action on Salt and Health).

KEY MESSAGES

- High levels of dietary sodium (consumed as common salt, sodium chloride) are associated with raised BP and adverse cardiovascular health.
- The report of a joint WHO/FAO Expert Consultation on 'Diet, Nutrition and the Prevention of Chronic Diseases' recommends that sodium intake of adults should be <85 mmol/day (2 g/day). Most adult populations around the world have mean sodium intakes well in excess of 100 mmol/day.
- Sodium intakes are commonly in excess of 100 mmol/day in children >5 years old.
- In European and North American countries, sodium intake is dominated by sodium added in manufactured foods.
- In Japan and China, salt added at home and soy sauce are the largest sources.

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