High intakes of dietary sodium are associated with elevated blood pressure levels and an increased risk of cardiovascular disease. National and international guidelines recommend reduced sodium intake in the general population, which necessitates population-wide surveillance. We assessed the utility of casual (spot) urine specimens in estimating 24-hour urinary sodium excretion as a marker of sodium intake in the International Cooperative Study on Salt, Other Factors, and Blood Pressure. There were 5,693 participants recruited in 1984–1987 at the ages of 20–59 years from 29 North American and European samples. Participants were randomly assigned to test or validation data sets. Equations derived from casual urinary sodium concentration and other variables in the test data were applied to the validation data set. Correlations between observed and estimated 24-hour sodium excretion were 0.50 for individual men and 0.51 for individual women; the values were 0.79 and 0.71, respectively, for population samples. Bias in mean values (observed minus estimated) was small; for men and women, the values were −1.6 mmol per 24 hours and 2.3 mmol per 24 hours, respectively, at the individual level and −1.8 mmol per 24 hours and 2.2 mmol per 24 hours, respectively, at the population level. Proportions of individuals with urinary 24-hour sodium excretion above the recommended levels were slightly overestimated by the models. Casual urine specimens may be a useful, low-burden, low-cost alternative to 24-hour urine collections for estimation of population sodium intakes; ongoing calibration with study-specific 24-hour urine collections is recommended to increase validity.
Organizations Expert Consultation recommended that adults consume less than 85 mmol/day (<2 g/day) of sodium (13). In
the United States, the Dietary Guidelines for Americans recom-
mend a reduction of sodium intake to less than 100 mmol/
day (<2.3 g/day) in the general population, with a further
reduction to 65 mmol/day (1.5 g/day) for individuals with
hypertension, diabetes, or chronic kidney disease, as well as
for African Americans and adults over 50 years of age (14).

Population surveys are required to monitor popula-
tion sodium intakes and assess the effectiveness of public
health efforts to reduce sodium intakes. Because of diffi-
culties in estimating sodium intakes using dietary surveys, mea-
surement of 24-hour urinary sodium excretion has become
the preferred method in population surveys (15–17). How-
ever, 24-hour collections are expensive and relatively bur-
densome to individuals. Estimating sodium excretion from
casual (spot) urine specimens is cheaper and less burden-
some but has not been extensively evaluated for use in popu-
lation surveys of sodium intake.

In the present study, we used casual and 24-hour urinary
sodium data collected in the International Cooperative Study
on Salt, Other Factors, and Blood Pressure (INTERSALT)
(8, 18, 19) to assess the utility of casual urine specimens for
estimation of sodium intake in Western (North American
and European) populations. The primary aim was to evaluate
whether casual urinary specimens are useful for estimation
of group mean sodium intakes; we also examined their rela-
tionship with individual intakes.

MATERIALS AND METHODS

Population samples and field methods

INTERSALT investigators collected standardized data on
casual urinary sodium concentrations and timed 24-hour
urinary sodium excretion for 10,079 men and women 20–59
years of age from 52 population samples in 32 countries (8,
study center was asked to recruit 200 men and women, strati-
fied by age and sex, from samples selected randomly or by
sampling from whole population groups (e.g., village dwell-
ers). Institutional ethics committee approval was obtained for
each collaborating center, and all participants gave informed
consent.

Before the onset of 24-hour urine collection, participants
were asked to provide a casual urine specimen. To guard
against under- and over-collection, start and end times of the
24-hour urine collections were supervised by clinic staff.
Urine collections were rejected if the participant reported
that "more than a few drops" were missing from the collect-
ion, if 24-hour urinary volumes were less than 250 mL, or if
the timing of the collection fell outside the range of 20–28
hours. A randomly selected 8% of the study sample provided
a second 24-hour urine specimen 3–6 weeks later for esti-
mation of within-individual variability of sodium excretion.
Aliquots of the casual and 24-hour urinary specimens were
frozen and sent to a central laboratory (Leuven, Belgium)
where several analytes were measured during 1985–1987,
including sodium, potassium (measured using emission
flame photometry), and creatinine (measured using Jaffé
reaction). Quality-control measures included repeated analy-
yses of specially collected “stock” urine specimens with
“low,” “medium,” and “high” sodium and potassium con-
centrations and analyses in which investigators were blinded
to which samples were split specimens. Technical error of
the laboratory measurements, based on split specimens, was
calculated for each population sample using the formula
\[ \sqrt{\frac{\sum d^2}{2N}} \]
where \( d \) is the difference between a pair of measurements
and \( N \) is the number of split pairs. The percentage of tech-
nical error per population sample (defined as 100 times the technical error divided by the mean value of
the split samples) was then calculated and averaged over the
samples, weighted by \( N \). The averaged percentages of tech-
nical errors were 1.4% (sodium), 1.9% (potassium), and
2.3% (creatinine) (21). Urinary excretions over 24 hours
were calculated as analyte concentration \( \times \) urine volume
corrected to 24 hours.

In the present study, we focused on data from the Western
population samples in INTERSALT. We excluded 2 samples
from Goodman, United States, with low mean urinary vol-
umes that indicated systematic under-collection; an Inuit
population from Labrador, Canada, who were unrepresenta-
tive of the wider North-American population; and a sample
from a coastal fishing village in St. John’s, Canada, who had
high sodium intakes that were found to be a marked popula-
tion outlier in the regression equations. This left data for the
analyses herein from 5,693 participants in 29 Western popu-
lation samples.

Statistical methods

Participants were assigned randomly (stratified by center,
age, and sex) to either test \( (n=2,948) \) or validation
\( (n=2,745) \) data sets. For the regression analyses, centers were
divided into 5 regions: North America, Northern Europe,
Eastern Europe, Southern Europe, and Western Europe. Sex-
specific regression equations estimating individual 24-hour
urinary sodium excretion from casual urinary sodium, potas-
sium, and creatinine concentrations, age, age^2, region, and
body mass index (weight (kg)/height (m)^2) were obtained for
participants from the test data set. Utility of inclusion of spe-
cific variables in the models was assessed using Student’s
t test, and model fit was assessed using adjusted \( R^2 \); regional
interactions in the slope of the casual sodium–24-hour sodium
regression association were tested using analysis of variance.

Regression coefficients obtained from the test data set
were applied to the validation data set; observed and esti-
mated 24-hour sodium excretion levels were compared at
the individual and mean population sample levels. Observed
population standard deviations were corrected for overdis-
per sample by using the square root of the reliability
coefficient previously derived for 24-hour sodium excretion,
0.387 (21, 22); reliability = s^2_p/(s^2_p + s^2_w), where
s^2_p is the between-person variance (i.e., an estimate of the
“true” population variance, which is unknown), s^2_w is the
within-person variance, and s^2_p + s^2_w is the observed vari-
ance. Estimated and observed proportions of the population
with urinary sodium excretions greater than 65 mmol in 24 hours and greater than 100 mmol in 24 hours were estimated assuming normal distributions. Bland-Altman plots, showing the mean of observed and estimated 24-hour sodium excretion values versus the difference between the 2 values, were used to assess bias (23).

To provide equations based on the totality of available data, overall models using data from all 5,693 participants were also computed. Statistical analyses were done by I.J.B. and Q.C. using SAS, version 9.2 (SAS Institute, Inc., Cary, North Carolina).

RESULTS

Descriptive statistics

Comprehensive descriptive statistics have been published previously (24). Among the 29 North American and European population samples analyzed here, the mean 24-hour sodium excretions for men ranged from 147.2 mmol (Charleroi, Belgium) to 240 mmol (Krakow, Poland) (Web Table 1, available at http://aje.oxfordjournals.org/); for women, they ranged from 117.8 mmol (Cottbus, Germany) to 167.5 mmol (Bassiano, Italy) (Web Table 2). Mean casual urinary sodium concentrations for men ranged from 109.2 mmol/L (Glostrup, Denmark) to 191.3 mmol/L (Krakow, Poland); for women, they ranged from 82.7 mmol/L (Glostrup, Denmark) to 186.8 mmol/L (Bassiano, Italy).

Regression models

Regression coefficients from individual-level linear regression models estimating 24-hour sodium excretion from casual urinary concentrations (sodium, potassium, and creatinine), region, body mass index, age, and age2 based on the test data set are shown in Web Table 3, and those based on data for all 5,693 participants are shown in Table 1. Consistently, all terms were significantly related to 24-hour sodium excretion except age and age2 in the men-only model. The intercept represents the β coefficient for North America, and the region β coefficients are with respect to North America. There was no interaction by region. For both men and women, coefficients were positive for casual urinary sodium concentration and body mass index and negative for casual urinary creatinine and potassium concentrations. The adjusted $R^2$ was 0.27 for men and 0.23 for women in the overall model (Table 1).

Models derived from the test data set (Web Table 3) were used to estimate 24-hour sodium excretion in the validation data set. Pearson $r$ correlations between individual observed and estimated 24-hour sodium excretions in the validation data set were 0.50 and 0.51, with β regression coefficients of 1.03 mmol and 0.86 mmol, among men and women, respectively (Figure 1A and 1B). Individual estimated 24-hour sodium excretions ranged from 11.9 mmol to 573.6 mmol in men and 7.7 mmol to 532.9 mmol in women. Bland-Altman plots showed overestimation of observed 24-hour sodium excretion.

Table 1. Sex-Specific Multiple Linear Regression Analyses of Individual 24-Hour Urinary Sodium Excretion in Test and Validation Data Sets Combined, International Cooperative Study on Salt, Other Factors, and Blood Pressure, 1984–1987

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men ($n = 2,841$)</th>
<th>Women ($n = 2,852$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\beta$ (SE)</td>
<td>Student's $t$ Test</td>
</tr>
<tr>
<td>Intercept (North America)</td>
<td>25.46 (16.63)</td>
<td>1.53</td>
</tr>
<tr>
<td>Casual sodium, mmol/L</td>
<td>0.46 (0.02)</td>
<td>20.24</td>
</tr>
<tr>
<td>Casual creatinine, mmol/L</td>
<td>-2.75 (0.22)</td>
<td>-12.70</td>
</tr>
<tr>
<td>Casual potassium, mmol/L</td>
<td>-0.13 (0.04)</td>
<td>-3.14</td>
</tr>
<tr>
<td>Body mass index$^d$</td>
<td>4.10 (0.31)</td>
<td>13.32</td>
</tr>
<tr>
<td>Age, years</td>
<td>0.26 (0.78)</td>
<td>0.34</td>
</tr>
<tr>
<td>Age$^2$, years$^2$</td>
<td>0.00 (0.01)</td>
<td>-0.30</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern Europe</td>
<td>23.17 (4.51)</td>
<td>5.13</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>39.56 (4.54)</td>
<td>8.71</td>
</tr>
<tr>
<td>Southern Europe</td>
<td>23.08 (4.03)</td>
<td>5.73</td>
</tr>
<tr>
<td>Western Europe</td>
<td>17.05 (3.96)</td>
<td>4.31</td>
</tr>
</tbody>
</table>

Abbreviation: SE, standard error.

$^a$ Adjusted $R^2 = 0.27$.

$^b$ Adjusted $R^2 = 0.23$.

$^c$ Coefficients for region are with respect to North America.

$^d$ Weight (kg)/height (m)$^2$. 

excretion at lower levels and underestimation at higher levels for both men and women (Figure 2A and 2B), with some marked outliers at high levels of sodium; however, the difference between observed and estimated mean 24-hour sodium excretion (i.e., bias) was small (−1.6 mmol and 2.3 mmol for men and women, respectively).
Figure 2. Bland-Altman plots comparing observed and estimated (casual urine) individual 24-hour sodium excretion levels in men (A; \(n = 1,369\)) and women (B; \(n = 1,376\)) in the validation data set for the International Cooperative Study on Salt, Other Factors, and Blood Pressure, 1984–1987. The upper limit of agreement equals the mean difference + 1.96 \times \text{standard deviation of the difference}, and the lower limit equals the mean difference − 1.96 \times \text{standard deviation of the difference}. 
Sample-level validation

Pearson $r$ correlations between observed and estimated sample mean 24-hour sodium excretions were 0.79 and 0.71, with $\beta$ regression coefficients of 1.17 mmol and 0.80 mmol, among men and women, respectively (Figure 3A and 3B). Bland-Altman plots did not indicate over- or underestimation of observed 24-hour sodium excretion, and bias in mean values (observed minus estimated) was small at $-1.8$ mmol and 2.2 mmol for men and women, respectively (Figure 4A and 4B). Two samples (from Moscow, Russia, and Hawaii, United States) fell outside the limits of agreement of the Bland-Altman plots for men, as did 2 (Cottbus and Heidelberg, Germany) for women. The pattern of results for observed and estimated sample median 24-hour sodium excretions was similar to that seen in analyses of sample means, though the adjusted $R^2$ was lower and the bias was larger (Web Figures 1 and 2).

Estimated sample standard deviations were mostly smaller than were observed 24-hour sodium excretion standard deviations (Table 2), despite correction of observed standard deviations for overdispersion based on the reliability estimate (see Materials and Methods). As a result, estimated proportions of individuals with 24-hour sodium intakes above 65 mmol and 100 mmol were generally higher for estimated 24-hour sodium excretion than for observed levels (Table 2). For example, based on the estimated standard deviations, the proportion of participants with a 24-hour sodium excretion greater than 100 mmol ranged from 96.4% to 100% for men and from 76.1% to 99.9% for women, as compared with 86.5% to 99.8% and 70.1% to 98.6% for men and women, respectively, based on observed standard deviations (corrected for overdispersion).

DISCUSSION

INTERSALT data indicated that models based on sodium, potassium, and creatinine concentrations from casual urine specimens may be useful for estimation of sample mean 24-hour sodium excretion. Using either threshold (65 mmol or 100 mmol), the 24-hour sodium excretion of the majority of North American and European individuals analyzed here was in excess of current recommended limits (14).

For both men and women, bias in estimated mean values was small for individual- and sample-based models. This may have relevance not only for estimation of mean population sodium excretion values using casual urine samples but also for population-based surveys with a cluster design, such as the ongoing US National Health and Nutrition Examination Survey (NHANES). In NHANES, casual urine specimens are collected, but sodium intake is estimated from 24-hour dietary recalls (25), which may be less accurate than estimates based on urinary data (15–17). Also, analysis of casual urine specimens at the cluster (sample) level in NHANES and other studies of similar design may result in less bias than analysis at individual level, but this would need to be validated with study-specific 24-hour urine collections.

Distributions of sodium excretion levels estimated by the regression models were typically less dispersed than were estimates based on the observed means and standard deviations, despite correction of the observed standard deviations for overdispersion due to within-person variability in sodium excretion. (Without such correction, the standard deviations of the observed data are too large; we recommend that the proposed simple correction procedure based on the reliability coefficient (intra-class correlation) of sodium excretion be applied to population data on urinary sodium excretion.) Accordingly, the proportion of individuals with values of urinary 24-hour sodium excretion above recommended levels of 65 mmol and 100 mmol tended to be slightly overestimated by the models; however, the extent of the bias varied by country and sex.

We did not set out to assess the validity of casual specimens for estimating 24-hour sodium excretion at the individual level. Compared with sample means, individual measurements of casual and 24-hour sodium are much more prone to “measurement error” because of intra-individual variability in sodium intakes, which contribute to the lower Pearson $r$ correlations for individual-level analyses compared with the group-level analyses. Nonetheless, despite wide variations in individual 24-hour sodium excretion, bias in the estimation of group mean levels from individual data was small.

There was a wide range of populations represented among the INTERSALT North American and European samples. The lack of significant regional interaction for the casual urinary sodium–24-hour sodium association suggests that our findings may be broadly generalizable. Despite this and the small bias overall in estimation of mean intakes, there may be error in estimation of intakes for individual population samples of more than 10 percentage points; we therefore recommend that in future studies, 24-hour urinary sodium specimens collected from representative subsamples of study participants be used to calibrate data from casual urine specimens. We have previously estimated for samples with a standard deviation of 24-hour urinary sodium excretion of approximately 60 mmol that a single 24-hour urine collection from 100 individuals would be sufficient to provide an estimate of the mean population sodium intake with 95% confidence intervals of plus or minus 12 mmol around the mean (26). Precision could be improved by using larger samples or by obtaining more than 1 specimen per person (27). The combination of casual urine specimens obtained from all participants in a study, with calibration against 24-hour collections from subsamples, could provide accurate estimates of mean 24-hour urinary sodium excretion while achieving a considerable saving in cost, logistics, and participant burden compared with use of 24-hour collections alone.

The inclusion of casual urinary creatinine concentrations, sex, age, and body mass index in the regression models was informed by previous work by Joossens et al. (28), who similarly developed equations for estimation of 24-hour urinary sodium excretion based on casual urinary data. We estimated 24-hour urinary sodium excretion directly from the regression models rather than working through an intermediate step based on estimation of 24-hour urinary creatinine; removal of 1 step should help reduce statistical error in the estimation procedure. In addition, we found that casual urinary potassium concentration (readily available at minimal
cost from standard urinary biochemistry) and age^2 (for women) added significantly to the regression models. The significant age^2 term observed for women is indicative of a curvilinear association between age and 24-hour sodium excretion. The association between urinary potassium concentration and 24-hour urinary sodium was inverse; the model therefore results in a lower estimated 24-hour sodium excretion for a given casual urinary sodium concentration when

Figure 3. Observed and estimated (casual urine) sample-level mean 24-hour sodium excretion for 29 samples in men (A) and women (B) in the validation data set for the International Cooperative Study on Salt, Other Factors, and Blood Pressure, 1984–1987.

accompanied by higher urinary potassium concentration. This could reflect the fact that higher potassium concentrations are indicative of a “healthier” diet that is richer in fruit and vegetables and lower in salt (29).

In other studies, investigators have reported significant positive correlations among casual urinary sodium concentrations, sodium/creatinine ratios, and 24-hour urinary sodium excretion (30–33). Using an analytical strategy similar to

Figure 4. Bland-Altman plots comparing observed and estimated (casual urine) sample-level mean 24-hour sodium excretion for 29 samples in men (A) and women (B) in the validation data set for the International Cooperative Study on Salt, Other Factors, and Blood Pressure, 1984–1987. The upper limit of agreement equals the mean difference +1.96 × standard deviation of the difference, and the lower limit equals the mean difference − 1.96 × standard deviation of the difference.
Table 2. Observed and Estimated 24-Hour Sodium Excretion by Sample in Men in the Validation Data Set (n = 1,369), International Cooperative Study on Salt, Other Factors, and Blood Pressure, 1984–1987

<table>
<thead>
<tr>
<th>Country and Sample</th>
<th>No. of Men</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Median</th>
<th>% &gt;65 mmol</th>
<th>% &gt;100 mmol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Observed</td>
<td>Estimated</td>
<td>Observed</td>
<td>Estimated</td>
<td>Observed</td>
</tr>
<tr>
<td>Belgium, Charleroi</td>
<td>39</td>
<td>149.6</td>
<td>175.9</td>
<td>33.5</td>
<td>30.5</td>
<td>140.8</td>
</tr>
<tr>
<td>Belgium, Gent</td>
<td>48</td>
<td>163.6</td>
<td>171.0</td>
<td>32.1</td>
<td>25.0</td>
<td>158.9</td>
</tr>
<tr>
<td>Denmark, Glostrup</td>
<td>48</td>
<td>158.3</td>
<td>168.3</td>
<td>40.2</td>
<td>35.5</td>
<td>152.3</td>
</tr>
<tr>
<td>Finland, Joensuu</td>
<td>48</td>
<td>193.8</td>
<td>187.0</td>
<td>35.8</td>
<td>29.2</td>
<td>189.6</td>
</tr>
<tr>
<td>Finland, Turku</td>
<td>48</td>
<td>173.8</td>
<td>174.8</td>
<td>38.3</td>
<td>25.2</td>
<td>159.1</td>
</tr>
<tr>
<td>Germany, Bernried</td>
<td>48</td>
<td>192.5</td>
<td>176.3</td>
<td>42.0</td>
<td>30.8</td>
<td>182.9</td>
</tr>
<tr>
<td>Germany, Cottbus c</td>
<td>48</td>
<td>174.3</td>
<td>184.3</td>
<td>44.9</td>
<td>31.9</td>
<td>152.8</td>
</tr>
<tr>
<td>Germany, Heidelberg</td>
<td>47</td>
<td>194.0</td>
<td>171.9</td>
<td>46.7</td>
<td>35.3</td>
<td>193.0</td>
</tr>
<tr>
<td>Hungary, Porcsalma</td>
<td>48</td>
<td>237.3</td>
<td>222.4</td>
<td>60.6</td>
<td>35.9</td>
<td>224.0</td>
</tr>
<tr>
<td>Iceland, Reykjavik</td>
<td>48</td>
<td>152.4</td>
<td>168.4</td>
<td>30.2</td>
<td>26.7</td>
<td>148.3</td>
</tr>
<tr>
<td>Italy, Bassiano</td>
<td>47</td>
<td>204.5</td>
<td>214.4</td>
<td>40.4</td>
<td>31.5</td>
<td>199.2</td>
</tr>
<tr>
<td>Italy, Gubbio</td>
<td>48</td>
<td>192.2</td>
<td>194.6</td>
<td>41.2</td>
<td>30.2</td>
<td>190.2</td>
</tr>
<tr>
<td>Italy, Mirano</td>
<td>48</td>
<td>189.2</td>
<td>185.7</td>
<td>37.5</td>
<td>32.9</td>
<td>183.6</td>
</tr>
<tr>
<td>Italy, Naples</td>
<td>48</td>
<td>171.6</td>
<td>186.8</td>
<td>31.9</td>
<td>27.2</td>
<td>173.2</td>
</tr>
<tr>
<td>Malta, Dingli</td>
<td>48</td>
<td>191.1</td>
<td>195.2</td>
<td>35.6</td>
<td>30.4</td>
<td>192.0</td>
</tr>
<tr>
<td>Netherlands, Zutphen</td>
<td>48</td>
<td>174.6</td>
<td>164.4</td>
<td>38.5</td>
<td>29.3</td>
<td>168.3</td>
</tr>
<tr>
<td>Poland, Krakow</td>
<td>48</td>
<td>239.7</td>
<td>222.6</td>
<td>48.6</td>
<td>27.3</td>
<td>235.6</td>
</tr>
<tr>
<td>Poland, Warsaw</td>
<td>48</td>
<td>221.8</td>
<td>211.8</td>
<td>59.4</td>
<td>37.5</td>
<td>210.6</td>
</tr>
<tr>
<td>Portugal, Cartaxo</td>
<td>48</td>
<td>200.2</td>
<td>192.1</td>
<td>51.8</td>
<td>33.9</td>
<td>199.6</td>
</tr>
<tr>
<td>Russia, Moscow</td>
<td>48</td>
<td>169.9</td>
<td>200.9</td>
<td>34.6</td>
<td>28.8</td>
<td>178.4</td>
</tr>
<tr>
<td>Spain, Manresa</td>
<td>48</td>
<td>209.5</td>
<td>194.4</td>
<td>39.8</td>
<td>34.1</td>
<td>212.5</td>
</tr>
<tr>
<td>Spain, Torrejon</td>
<td>48</td>
<td>190.7</td>
<td>187.6</td>
<td>50.6</td>
<td>37.6</td>
<td>184.7</td>
</tr>
<tr>
<td>United Kingdom, Belfast</td>
<td>48</td>
<td>151.7</td>
<td>157.1</td>
<td>36.8</td>
<td>31.5</td>
<td>150.9</td>
</tr>
<tr>
<td>United Kingdom, Belfast</td>
<td>48</td>
<td>168.1</td>
<td>167.0</td>
<td>26.9</td>
<td>17.1</td>
<td>163.0</td>
</tr>
<tr>
<td>United Kingdom, South Wales</td>
<td>48</td>
<td>183.1</td>
<td>176.4</td>
<td>37.2</td>
<td>31.0</td>
<td>185.1</td>
</tr>
<tr>
<td>United States, Chicago</td>
<td>47</td>
<td>144.3</td>
<td>161.9</td>
<td>38.1</td>
<td>33.6</td>
<td>150.4</td>
</tr>
<tr>
<td>United States, Hawaii</td>
<td>45</td>
<td>144.2</td>
<td>176.3</td>
<td>40.1</td>
<td>42.3</td>
<td>127.5</td>
</tr>
<tr>
<td>United States, Jackson (Black)</td>
<td>40</td>
<td>170.3</td>
<td>167.1</td>
<td>59.7</td>
<td>29.2</td>
<td>152.9</td>
</tr>
<tr>
<td>United States, Jackson (White)</td>
<td>48</td>
<td>155.2</td>
<td>157.1</td>
<td>40.7</td>
<td>32.2</td>
<td>147.5</td>
</tr>
</tbody>
</table>

a Observed standard deviation corrected for overdispersion by multiplying by $\sqrt{0.387}$.

b Calculated from the mean and standard deviation, assuming a normal distribution.

c Former German Democratic Republic (East Germany).
Table 3. Observed and Estimated 24-Hour Sodium Excretion by Sample in Women in the Validation Data Set \((n = 1,376)\), International Cooperative Study on Salt, Other Factors, and Blood Pressure, 1984–1987

<table>
<thead>
<tr>
<th>Country and Sample</th>
<th>No. of Women</th>
<th>Mean Observed</th>
<th>Mean Estimated</th>
<th>Standard Deviation(^{a})</th>
<th>Median Observed</th>
<th>Median Estimated</th>
<th>% &gt;65 mmol(^{b})</th>
<th>% &gt;100 mmol(^{b})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium, Charleroi</td>
<td>37</td>
<td>123.9</td>
<td>132.6</td>
<td>31.6</td>
<td>22.2</td>
<td>116.4</td>
<td>131.7</td>
<td>95.6</td>
</tr>
<tr>
<td>Belgium, Ghent</td>
<td>48</td>
<td>120.8</td>
<td>130.6</td>
<td>24.2</td>
<td>21.5</td>
<td>112.8</td>
<td>126.8</td>
<td>98.2</td>
</tr>
<tr>
<td>Denmark, Glostrup</td>
<td>48</td>
<td>117.4</td>
<td>126.0</td>
<td>24.4</td>
<td>20.5</td>
<td>112.2</td>
<td>126.4</td>
<td>97.4</td>
</tr>
<tr>
<td>Finland, Joensuu</td>
<td>48</td>
<td>149.0</td>
<td>137.2</td>
<td>32.4</td>
<td>23.4</td>
<td>146.5</td>
<td>136.7</td>
<td>99.3</td>
</tr>
<tr>
<td>Finland, Turku</td>
<td>48</td>
<td>138.2</td>
<td>132.6</td>
<td>33.1</td>
<td>19.6</td>
<td>131.8</td>
<td>131.8</td>
<td>98.0</td>
</tr>
<tr>
<td>Germany, Bernried</td>
<td>47</td>
<td>157.5</td>
<td>137.0</td>
<td>34.3</td>
<td>23.2</td>
<td>150.1</td>
<td>137.3</td>
<td>99.5</td>
</tr>
<tr>
<td>Germany, Cottbus(^c)</td>
<td>48</td>
<td>118.0</td>
<td>141.1</td>
<td>24.7</td>
<td>18.9</td>
<td>113.9</td>
<td>142.9</td>
<td>97.4</td>
</tr>
<tr>
<td>Germany, Heidelberg</td>
<td>48</td>
<td>159.9</td>
<td>131.7</td>
<td>31.4</td>
<td>20.3</td>
<td>158.7</td>
<td>130.3</td>
<td>99.8</td>
</tr>
<tr>
<td>Hungary, Porcsalma</td>
<td>48</td>
<td>156.2</td>
<td>165.9</td>
<td>33.1</td>
<td>27.6</td>
<td>156.6</td>
<td>171.9</td>
<td>99.5</td>
</tr>
<tr>
<td>Iceland, Reykjavik</td>
<td>48</td>
<td>115.0</td>
<td>126.6</td>
<td>24.1</td>
<td>22.8</td>
<td>113.4</td>
<td>126.1</td>
<td>96.9</td>
</tr>
<tr>
<td>Italy, Bassiano</td>
<td>48</td>
<td>170.6</td>
<td>178.0</td>
<td>39.0</td>
<td>25.0</td>
<td>162.7</td>
<td>182.0</td>
<td>99.5</td>
</tr>
<tr>
<td>Italy, Gubbio</td>
<td>48</td>
<td>161.5</td>
<td>156.4</td>
<td>32.7</td>
<td>23.3</td>
<td>159.3</td>
<td>159.6</td>
<td>99.7</td>
</tr>
<tr>
<td>Italy, Mirano</td>
<td>48</td>
<td>153.3</td>
<td>151.3</td>
<td>29.5</td>
<td>23.2</td>
<td>156.0</td>
<td>148.4</td>
<td>99.8</td>
</tr>
<tr>
<td>Italy, Naples</td>
<td>48</td>
<td>153.6</td>
<td>153.5</td>
<td>30.2</td>
<td>23.5</td>
<td>141.7</td>
<td>154.8</td>
<td>99.7</td>
</tr>
<tr>
<td>Malta, Dingli</td>
<td>48</td>
<td>153.0</td>
<td>150.2</td>
<td>38.0</td>
<td>25.0</td>
<td>136.8</td>
<td>152.8</td>
<td>98.6</td>
</tr>
<tr>
<td>Netherlands, Zutphen</td>
<td>48</td>
<td>129.5</td>
<td>121.6</td>
<td>25.5</td>
<td>23.8</td>
<td>126.6</td>
<td>123.8</td>
<td>99.0</td>
</tr>
<tr>
<td>Poland, Krakow</td>
<td>48</td>
<td>157.5</td>
<td>159.7</td>
<td>38.0</td>
<td>21.1</td>
<td>147.4</td>
<td>158.9</td>
<td>98.9</td>
</tr>
<tr>
<td>Poland, Warsaw</td>
<td>48</td>
<td>162.1</td>
<td>147.4</td>
<td>46.7</td>
<td>24.6</td>
<td>150.0</td>
<td>141.5</td>
<td>97.6</td>
</tr>
<tr>
<td>Portugal, Cartaxo</td>
<td>49</td>
<td>157.1</td>
<td>161.7</td>
<td>42.4</td>
<td>28.1</td>
<td>144.3</td>
<td>162.6</td>
<td>98.0</td>
</tr>
<tr>
<td>Russia, Moscow</td>
<td>47</td>
<td>148.9</td>
<td>148.5</td>
<td>38.6</td>
<td>27.6</td>
<td>145.9</td>
<td>149.8</td>
<td>97.9</td>
</tr>
<tr>
<td>Spain, Manresa</td>
<td>48</td>
<td>155.7</td>
<td>148.7</td>
<td>35.1</td>
<td>24.8</td>
<td>149.0</td>
<td>149.2</td>
<td>99.3</td>
</tr>
<tr>
<td>Spain, Torrejon</td>
<td>48</td>
<td>158.6</td>
<td>160.4</td>
<td>26.5</td>
<td>27.4</td>
<td>149.8</td>
<td>160.7</td>
<td>100.0</td>
</tr>
<tr>
<td>United Kingdom, Belfast</td>
<td>48</td>
<td>153.0</td>
<td>129.9</td>
<td>30.9</td>
<td>28.9</td>
<td>149.1</td>
<td>131.5</td>
<td>99.6</td>
</tr>
<tr>
<td>United Kingdom, Birmingham</td>
<td>48</td>
<td>146.5</td>
<td>136.9</td>
<td>28.4</td>
<td>25.5</td>
<td>142.4</td>
<td>132.5</td>
<td>99.6</td>
</tr>
<tr>
<td>United Kingdom, South Wales</td>
<td>48</td>
<td>130.2</td>
<td>137.0</td>
<td>28.7</td>
<td>22.5</td>
<td>126.7</td>
<td>134.2</td>
<td>98.2</td>
</tr>
<tr>
<td>United States, Chicago</td>
<td>48</td>
<td>135.0</td>
<td>124.9</td>
<td>48.6</td>
<td>24.0</td>
<td>120.4</td>
<td>126.7</td>
<td>90.9</td>
</tr>
<tr>
<td>United States, Hawaii</td>
<td>44</td>
<td>145.7</td>
<td>141.8</td>
<td>42.5</td>
<td>33.0</td>
<td>138.6</td>
<td>143.9</td>
<td>96.3</td>
</tr>
<tr>
<td>United States, Jackson (Black)</td>
<td>48</td>
<td>117.6</td>
<td>126.4</td>
<td>33.4</td>
<td>33.3</td>
<td>123.0</td>
<td>132.6</td>
<td>92.3</td>
</tr>
<tr>
<td>United States, Jackson (White)</td>
<td>48</td>
<td>132.4</td>
<td>117.5</td>
<td>34.5</td>
<td>24.7</td>
<td>119.9</td>
<td>117.9</td>
<td>96.5</td>
</tr>
</tbody>
</table>

\(^{a}\) Observed standard deviation corrected for overdispersion by multiplying by \(\sqrt{0.387}\).

\(^{b}\) Calculated from the mean and standard deviation, assuming a normal distribution.

\(^{c}\) Former German Democratic Republic (East Germany).
that from our study, Tanaka et al. (34) developed an equation to estimate 24-hour urinary sodium excretion from casual specimens from 591 Japanese INTERSALT participants and validated the equation in a sample of 513 individuals from another Japanese population sample. The authors noted that circadian patterns in sodium excretion would likely lead to under- or overestimation of 24-hour sodium excretion for some individuals, but if the casual specimen collection times were distributed randomly through the day, the impact on group means would be small. Consistent with our findings and those of others (35), Tanaka et al. concluded that casual urinary specimens may be useful for estimating the mean population 24-hour sodium excretion and charting trends in population means over time.

Overnight urine collection has also been proposed as a low-burden alternative to 24-hour collection (36–38). However, differential diurnal excretion patterns have been observed for nonhypertensive and hypertensive individuals, by sex, and by race (37, 39, 40). Thus, estimates of sodium intake from overnight urine collections may be biased by, for example, the mix of hypertensive and normotensive individuals in the sample.

Our study has limitations. It is based on casual and 24-hour urinary data collected from multiple locations in North America and Europe in the 1980s. Since then, urinary excretion patterns, as well as correlations between casual and 24-hour urinary data, may have altered, reflecting changes in dietary and lifestyle habits over the ensuing 20–30 years. On the other hand, all specimens were collected using standardized methods according to strict protocol; these will have minimized differences between samples and countries. Casual urinary specimens taken at different times of day can be influenced by diurnal variation, including in urinary creatinine concentrations (41), because creatinine excretion is influenced by meat intake (42, 43), with potentially high within-person diurnal variation (44, 45). Fluid intake can also vary over the day, possibly impacting urinary concentrations (46). In addition, we did not have sufficient data to test whether our equations were suitable for important population subgroups, for example, African Americans or hypertensive individuals. Calibration against 24-hour urinary excretion data is recommended to check performance of the equations in subgroups if specific data on these strata are required.

In summary, casual urinary specimens may be a valid low-burden, low-cost alternative to 24-hour collections for estimation of mean population sodium intakes (and by extension, estimation of trends over time), though study-specific calibration against 24-hour collections to increase validity is recommended. Also, these data may be used to estimate the proportion of the population with dietary sodium intakes above specific threshold values within a few percentage points. Reliable, ongoing population-wide data on sodium intakes are necessary to monitor the effectiveness of public health efforts to reduce sodium intakes for the prevention of high blood pressure and major cardiovascular diseases (47).

ACKNOWLEDGMENTS

Author affiliations: Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London, United Kingdom (Ian J. Brown, Queenie Chan, Paul Elliott); Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago, Illinois (Alan R. Dyer, Jeremiah Stamler); Epidemiology and Surveillance Branch, Division for Heart Disease and Stroke Prevention, National Center for Chronic Disease and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia (Mary Cogswell); Department of Health Science, Shiga University of Medical Science, Otsu, Japan (Hirotugu Ueshima); and Medical Research Council–Health Protection Agency Centre for Environment and Health, School of Public Health, Imperial College London, London, United Kingdom (Paul Elliott).

This work was supported by United States Centers for Disease Control and Prevention contract number 200–2010–43842 (Atlanta, Georgia), The International Cooperative Study on Salt, Other Factors, and Blood Pressure (INTERSALT) was supported by the Council on Epidemiology and Prevention of the World Heart Federation (Geneva, Switzerland); the World Health Organization (Geneva, Switzerland); the International Society of Hypertension (Ware, United Kingdom); the Wellcome Trust (London, United Kingdom); the National Heart, Lung, and Blood Institute, National Institutes of Health (Bethesda, Maryland); the Heart and Stroke Foundation of Canada (Ottawa, Ontario); the British Heart Foundation (London, Great Britain); the Japan Heart Foundation (Tokyo, Japan); Netherlands Heart Foundation (Den Haag, Netherlands); the Chicago Health Research Foundation (Chicago, Illinois); the Belgian National Research Foundation (Brussels, Belgium); Parastatal Insurance Company (Brussels, Belgium); and by many national agencies supporting local studies. P.E. acknowledges support from the National Institute for Health Research (NIHR) Biomedical Research Centre at Imperial College Healthcare National Health Service (NHS) Trust and Imperial College. P.E. is an NIHR senior investigator.

We thank all INTERSALT staff at local, national, and international centers for their invaluable efforts; a partial listing of these colleagues is given in reference 18.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health.

Conflict of interest: none declared.

REFERENCES


