Comparison of Sodium and Potassium Intake with Excretion

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SUMMARY Nine well-motivated adults, knowledgeable about nutrition, kept food records, saved food portions equal to what had been eaten, and collected 24-hour urine samples for 3 consecutive days. Estimates of sodium and potassium intake were calculated from food table analyses of written food records and from flame photometric analyses of food portions. For each subject the mean of the estimates for each of the 3 days was compared with the mean of urine analyses for sodium and potassium for each of the 3 days. For the group of nine subjects, the average estimate of sodium intake from analyses of food records was 11% lower than the average estimate of urinary sodium excretion; the average estimate of sodium intake from analysis of food portions was 2% higher than urinary sodium excretion. For individuals, there were large differences between estimates of intake and measurement of sodium excretion. For the group of nine subjects, the average estimate of potassium intake from analysis of food records was less than 1% lower than the average estimate of potassium urinary excretion; the average estimate of potassium intake from analysis of food portions was 13% higher than potassium urinary excretion. For individuals, as with sodium, there were large differences between estimates of intake and measurement of potassium excretion. (Hypertension 2: 695-699, 1980)

KEY WORDS sodium • potassium • urinary excretion measurements

THE PURPOSE of this study was to determine whether in free living adults measurement of sodium and potassium from food ingested yields a valid estimate of sodium and potassium excreted in the urine. This is of interest because 24-hour urinary excretion, which is believed to provide the best estimate of sodium intake, cannot be measured in free living infants and is difficult to measure in free living adults. In a prior study of 6-month-old infants, sodium intake was assessed from food records, and a positive association was found between sodium intake and systolic blood pressure.1 When the infants were reexamined at 15 months of age, the association between sodium intake and systolic pressure was no longer present. We wondered whether the more complex food intakes of 15-month-old infants rendered the assessment of sodium intake from food records invalid.

Two studies have reported comparison between sodium intake and sodium urinary excretion. In one study of 11 adults, after discussions with the subjects on the importance of lowering sodium intake, a single 24-hour diet recall was found to be a reliable measure of 24-hour urine excretion of sodium and potassium.2 In this study, the diet recall analysis consistently underestimated sodium intake by 30%. In another study, when intake and urinary excretion of sodium were averaged over a period of 28 days, they were almost identical in 10 young men with relatively low sodium intake, and were highly correlated in 10 young men with moderate sodium intake.3

Other studies have reported wide fluctuations in 24-hour urinary sodium excretion in subjects on constant sodium intakes.4-5 Several factors have been identified that influence this variability: oscillation of balance for water and electrolytes,6 level of sodium intake,7 level of potassium intake,1 degree of hydration,1 and the delay in equilibration following a change in intake.6,7,8

In the present study of adults, estimates of sodium intake from food table analyses of written food records and from flame photometric analyses of food portions are compared to 24-hour urine excretion of sodium. Estimates of potassium intake and excretion are also compared.
Method

Adult subjects, rather than infants, were selected so that 24-hour urine collections could be obtained. To ensure a high degree of compliance with protocol, two groups of adults were recruited: six nutrition students at the University of Pittsburgh Graduate School of Public Health who were studying assessment of food intake, and seven members of our research team. Data were collected during December and January.

Subjects received both oral and written instructions for urine collection, and then kept a written record of the time and amount of each voiding. To allow for a lag time between eating and urine excretion, a 24-hour period was defined as being terminated by collection of the first morning specimen on the day following the day in which food portions were collected. Therefore, each first morning specimen was kept separate and analyzed separately from the rest of the urine collected in that same calendar day. Because of the variation in daily sodium excretion, urines were collected for 3 consecutive days, with a first morning specimen only being collected on the fourth day.

Subjects were instructed orally and in writing to record times of ingestion and to describe each food item and the amount ingested. In addition, they saved portions equal in amount to all of the foods and liquids ingested. A salt shaker containing approximately 15 g of salt was provided for each of the 3 days. The subjects were instructed not to use salt in cooking or food preparation, but to add salt to their food from the salt shaker provided. Each salt shaker was weighed before and after each day's use to determine the amount of salt ingested. Written food records were analyzed for sodium and potassium by means of a computer file of nutrient values of foods based on U. S. Department of Agriculture Handbook 456, plus lists of supplementary food items. Food portions were blanderized but not diluted or digested prior to analysis; the solids were spun out, and the supernatants analyzed for sodium and potassium. Sodium and potassium concentrations of urine and food supernatants were measured by flame photometry using Instrumentation Laboratory Model 443 flame photometer with an internal lithium standard. Blood samples were collected from each of the seven research team subjects for measurement of plasma creatinine on one of the days of food and urine collection, to permit calculation of creatinine clearance.

Results

Mean 24-hour urine creatinine of each subject was compared with published values for age- and sex-specific means. The latter data were utilized because they provided age- and sex-specific means and standard deviations for creatinine excretion. Adults in New Zealand did not differ in height from United States adults, and differences in weight for age and sex groups varied from not significant to a maximum of less than 4%. Since differences between the two populations in body mass and presumably in muscle mass seemed small, it was assumed that differences in creatinine excretion, similarly, would be small. Data from three of the nutrition students were eliminated because their mean creatinine excretions were more than 1.2 standard deviations below the New Zealand mean. These data were rejected because of the probability that urine collection was incomplete, and therefore urine sodium and potassium excretion rates not valid. Data from one of the research team members were eliminated because urine samples were lost. For the remaining nine subjects (seven women, two men) mean creatinine and mean urine volume were compared to age- and sex-specific means in table 1. Daily electrolyte excretions for the nine subjects are included.

Creatinine clearance calculated for further assessment of the adequacy of urine collection ranged from 83 to 105 ml/min in five subjects, and in one, 151 ml/min. The usual range of creatinine clearance is 60 to 110 ml/min. The creatinine excretion and creatinine clearance data all indicated that adequate 24-hour urine samples were obtained in these subjects. The average amount of sodium found in 24-hour urine samples for the nine subjects ranged from 76 to 153 mEq, which was similar to the average of 123 mEq for 11 subjects trained to lower sodium intake. It was, however, lower than average levels observed in the New Zealand population for age- and sex-specific groups, 139 to 149 mEq for females and 177 to 184 mEq for men. In another study of 142 males with high normal or borderline elevation of blood pressure who were undergoing a trial of primary prevention of hypertension, the average of four 24-hour urine measurements of sodium excretion ranged from 156 to 196 mEq.

In the present study, for the group of nine subjects, the estimate of sodium intake from food portions agreed closely with the measurement of urinary excretion of sodium. The average estimate of sodium intake from food portions for the nine subjects was 2 mEq higher than the average measurement of urinary excretion (table 2). The average estimate of sodium intake from food records was 13 mEq lower than the average urinary excretion.

For individuals, differences between the estimate of sodium intake from food portion and urine measurement ranged from -36% to +44% (SD 36.4); differences between the estimate of sodium intake from food record and urine measurement ranged from -51% to +61% (SD 39.6). The differences between food record and urine measurement of sodium exceeded ± 25% in four of the nine subjects.

Differences between sodium intake as estimated by food portion analysis and urine excretion did not seem to be a function of the magnitude of fluctuations in daily urine volume either as reflected by variability in daily creatinine excretion or by variability in daily urine collected. The absolute differences among each of the three daily creatinine excretions and the mean creatinine excretion for each subject were calculated.
and then averaged. The squares of these absolute differences for each subject were calculated also and then averaged. The four subjects with the largest differences in sodium between food portion analysis and urine excretion were compared with the four subjects with the smallest differences. The absolute differences and the squares of the differences in daily sodium between food portion analysis and urine excretion were compared with the four subjects. The same analyses with daily urine excretion were compared with the four subjects. The estimates of sodium intake for each individual appeared inadequate. There were large differences in urinary excretion of sodium were reported in earlier studies of subjects on constant sodium intakes. 

For the group of nine subjects, the average estimate of potassium intake from food portions averaged 7 mEq higher than the average measurement of urinary potassium. The average estimate of potassium intake from food records averaged less than 1 mEq lower than measurement from urine samples (table 3).

For individuals, differences between food portion and urine measurement ranged from −7% to +31% (SD 6.6); differences between food record and urine measurement ranged from −22% to +26% (SD 10.7).

**Discussion**

In a group of 13 well-motivated adult subjects, data from four had to be rejected because urine collection appeared inadequate. There were large differences in the estimates of sodium intake for each individual based on the mean of the values for each of 3 days for either food records or food portions compared to measurement of sodium excretion in three 24-hour urine samples. Similar differences between intake and urinary excretion of sodium were reported in earlier studies of subjects on constant sodium intakes. From these studies data were selected for the last 3 days of measurement for each subject (table 4); average differences for individuals between sodium intake and excretion ranged from −18% to +52% (SD 23.4). The large differences found in these prior studies support the conclusion of the present study.
TABLE 3. Average Potassium Intake and Excretion Per Day (mEq)

<table>
<thead>
<tr>
<th>Ss</th>
<th>Food record</th>
<th>Food portion</th>
<th>Urine</th>
<th>Food portion—urine</th>
<th>Difference %</th>
<th>Food record—urine</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51</td>
<td>67</td>
<td>52</td>
<td>15</td>
<td>29</td>
<td>-2</td>
<td>-4</td>
</tr>
<tr>
<td>2</td>
<td>62</td>
<td>68</td>
<td>52</td>
<td>16</td>
<td>31</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>53</td>
<td>61</td>
<td>58</td>
<td>3</td>
<td>5</td>
<td>-5</td>
<td>-8</td>
</tr>
<tr>
<td>4</td>
<td>55</td>
<td>76</td>
<td>70</td>
<td>6</td>
<td>9</td>
<td>-15</td>
<td>-22</td>
</tr>
<tr>
<td>5</td>
<td>48</td>
<td>57</td>
<td>62</td>
<td>-5</td>
<td>-7</td>
<td>-13</td>
<td>-22</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>59</td>
<td>51</td>
<td>9</td>
<td>17</td>
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<td>62</td>
<td>60</td>
<td>57</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>83</td>
<td>78</td>
<td>66</td>
<td>12</td>
<td>18</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>58.4</td>
<td>66.2</td>
<td>57.8</td>
<td>7.4</td>
<td>13.6</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

Standard deviation 6.6 10.7

that, based upon 3-day collection in well-motivated adults who were knowledgeable regarding nutrition, neither food record estimates nor analyses of food portions provided valid measures for individuals of 3-day urine excretions of sodium.

When, in a previous study, sodium intake for individuals was averaged over a 28-day period, there was close agreement with urinary sodium averaged over this same period. It is likely, therefore, that for some number of days greater than 3 and less than 28, measurement of sodium intake from analysis of food portions would provide valid estimates of urinary excretion of sodium in individuals.

The present study was undertaken to assess the validity of food intake measures of electrolytes as indices of urinary excretion of electrolytes. In addition to the issue of validity, there is also the question of feasibility and difficulty in measuring either food intake or urinary excretion. Among our well-motivated subjects, there was the subjective impression that the collection and analysis of food portions was approximately as difficult a task, and involved as much inconvenience, as obtaining 24-hour urine samples.

Food record estimates of sodium intake were 11% lower than urinary excretion in the present study (table 2) and 30% lower than urinary excretion in a prior study. Perhaps the subjects, aware of the desirability of minimizing sodium intake, had underestimated the quantities of sodium-containing foods in their food records. Food records, in the present study, did not underestimate the potassium-containing foods ingested. An alternate hypothesis is that the food table values underestimate the sodium content of numerous foods. There seems no plausible reason for this. Further, the food table values do provide valid measures of the potassium content of foods.

TABLE 4. Average Sodium Excretion Per Day (mEq) of Subjects on Constant Sodium Intake in Other Studies

<table>
<thead>
<tr>
<th>Ref no.</th>
<th>Ss</th>
<th>Sodium intake</th>
<th>24-Hour urine sodium excretion</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>FW</td>
<td>149</td>
<td>Day 1 243</td>
<td>-10</td>
</tr>
<tr>
<td>3</td>
<td>BM</td>
<td>156</td>
<td>Day 2 122</td>
<td>-16</td>
</tr>
<tr>
<td>3</td>
<td>SV</td>
<td>99</td>
<td>Day 3 112</td>
<td>-5</td>
</tr>
<tr>
<td>3</td>
<td>JP</td>
<td>108</td>
<td>Day 1 121</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>EH</td>
<td>109</td>
<td>Day 2 99</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>FS</td>
<td>129</td>
<td>Day 3 87</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>KR</td>
<td>140</td>
<td>Day 1 96</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>DM</td>
<td>141</td>
<td>Day 2 87</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>NC</td>
<td>146</td>
<td>Day 3 91</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>FMc</td>
<td>123</td>
<td>Day 1 124</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>DB</td>
<td>150</td>
<td>Day 2 121</td>
<td>6</td>
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<tr>
<td>2</td>
<td>AT</td>
<td>150</td>
<td>Day 3 121</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>133.3</td>
<td>126.8</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Standard deviation 23.4
Results from the present study of nine subjects suggest that, despite the large differences for individuals between intake and excretion of sodium, the average of the measurements of sodium in food (food portion analysis or ingestion of prescribed amounts of sodium) will not deviate from average urinary excretion by more than 2% to 5% (tables 2 and 4). For epidemiological study, therefore, measurement of sodium intake by analysis of food portions over a 3-day period should provide a fairly accurate measure of average sodium excretion for the group. It should be possible, for example, to obtain reasonable estimates of urinary excretion of sodium from measurement of sodium in food ingested in groups with different blood pressure levels, including groups containing only nine or more subjects. Measurement of sodium intake by analysis of food records is not expected to provide the degree of accuracy as analysis of food portions.

Several of the differences for individuals between 3-day estimates of potassium intake and urinary excretion exceeded 25%, and a considerable number exceeded 10%. Consequently, measures of potassium intake are not accurate estimates of urinary excretion over a 3-day period. Differences for individuals between potassium intake and urinary excretion showed a smaller variance than for sodium (tables 2 and 3). For this group of nine subjects, the average estimate of potassium intake deviated from the average urinary excretion by less than 8%. For groups of this size or larger, therefore, 3-day estimates of intake may provide reasonable estimates of urinary excretion of potassium.

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