Sodium and Potassium Balance and Their Relation to Nutrient Intakes in Young Adult Men and Women

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Abstract

This study was conducted to investigate sodium and potassium balances, as well as correlations among the relating factors in adult males and females. We collected blood, urine and feces samples as well as a dietary intake survey from 50 subjects. Then, we analyzed the sodium and potassium contents in blood, urine and feces, and evaluated their state of balance. The average ages of the study targets were 24.7 years old for males and 22.8 years old for females. The daily energy intake by the males was 1733.4 kcal and by the females was 1570.3 kcal. Sodium intakes were 138.3 mEq and 127.5 mEq for males and females, respectively. Potassium intakes were 43.1 mEq and 49.3 mEq, respectively. The daily excretions of sodium through urine were 136.6 mEq by males and 97.0 mEq by females and the excretions through feces were 2.2 mEq and 2.0 mEq, respectively. The daily excretions of potassium through urine were 20.2 mEq and 16.5 mEq by males and females respectively, and the excretions through feces were 7.7 mEq and 7.5 mEq male to female. The retention rates of sodium were 11.7% and 14.1% male to female, respectively, and the apparent absorption rates were 98.5% and 97.8% . Additionally, the retention rates of potassium were 32.9% and 39.8% and the apparent absorptions were 81.9% and 81.3% , both male and female. It was noted that, overall, the sodium intake of adult males and females is still higher than the recommended daily sodium intake, while the potassium intakes and excretions were found to be lower. Based on the results of this study, nutritional guidance and education is recommended to encourage decreased sodium intake and increased potassium intake, according to recommended standards.

Key words: sodium balance, potassium balance, nutrient intakes

INTRODUCTION

As a component of extracellular fluid, sodium provides important physiological functions, such as maintaining the water and acid-alkali balance, regulating cellular membrane potential, moving nutrients through the cellular membrane and regulating the volume of blood (1). Since the physiological requirement of sodium is very low, there is no concern for sodium deficiency. Therefore, U.S., Japan and Korea do not have any recommended sodium intakes (2). However, excessive intake of sodium induces hypertension, which is relevant to most cerebrovascular diseases, such as cerebral hemorrhage and cerebral infarction. Traditionally, Korea has high levels of sodium intake, and these diseases are high in the list of the causes of death in Korea. Therefore, reduction in sodium intake is being encouraged (3-6). Even though the sodium intake levels have been remarkably lowered through various efforts, they are still higher in Korea than in the U.S. and Japan. Therefore, studies are necessary to continuously examine sodium intake and excretion.

As a major positive ion contained primarily in extracellular fluid, potassium maintains cellular membrane potential and determines the strength of ions in the intracellular fluid (7). Ionized potassium, together with sodium ion, regulates muscle contraction and relaxation by controlling impulse and stimulus transmission in nerve and muscle cells. In particular, it serves an important role in regulating cardiac muscle contraction (2). The minimum requirement of potassium is yet to be clearly specified. Since potassium intake suppresses increases in blood pressure caused by excessive sodium intake, some have posited that potassium intake should increase as sodium intake increases (2,8).

There are a number of indices to estimate sodium and potassium requirements. Of them, the balance state and serum concentration are commonly used. Studies to date have reported that the excretion of sodium through urine is approximately 90–95% of intake and that the excretion through feces is approximately 5% (3,9). In a healthy adult, potassium absorption is approximately

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and feces were collected over 24 hrs using plastic urine
sample bottles and pollution-free vinyl bags treated with 0.4% EDTA for over 12 hrs and filled with 1 mL
of toluene. The total weights of the collected urine and
feces were measured. Then, urine was processed through
centrifugation and the supernatant was collected. Feces
were well mixed and approximately 1 g was taken,
which was broken down using a microwave digestion
system (Ethos touch control, Milestone Inc., Italy) to cre-
tate test fluid. Then, using the ICP-AES (Thermo elemental
Ltd., UK), quantitative analysis of sodium and potassium
was conducted. To prevent contamination of minerals,
all instruments used in the experiment were thoroughly
washed, then plastic and glass products were submerged
in 0.4% EDTA solution and in an undiluted nitric acid
solution for 24 hrs or longer. The instruments were then
washed three times or more with distilled-deionized wa-
ter and all moisture was removed using a dryer.

**Statistical analysis**

The means and standard deviations of all results ob-
tained during the experiment were calculated using the
SAS program (ver. 8.1). For differences in analysis re-
sults per male and female, unpaired Student’s t-test was
used. As for the relevance between each factor, the eval-
uation was conducted using the Pearson's correlation co-
efficient (r) and its significance verification. The sig-
ificances of results were evaluated at an α level of 0.05.

**RESULTS AND DISCUSSION**

**General characteristics**

The general characteristics of the study targets are as
shown in Table 1. The average ages of male and female
subjects were 24.7 and 22.8 respectively. The heights
were 173.2 cm and 161.1 cm, weights were 73.6 kg and
55.3 kg and body mass index (BMI) were 24.6 kg/m²
and 21.6 kg/m², respectively. The heights and weights
of study subjects were similar to the 174.0 cm and 73.1
kg for males and the 160.7 cm and 53.3 kg for females
aged 19~29 as described by the Korea National Health
and Nutrition Examination Survey 2007 (15). As for the

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=23)</th>
<th>Female (n=27)</th>
<th>Total (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>24.7±2.4*</td>
<td>22.8±0.7**</td>
<td>23.7±1.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.2±4.1</td>
<td>161.1±3.8***</td>
<td>166.6±7.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.6±12.7</td>
<td>55.8±6.6***</td>
<td>64.0±13.3</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.6±4.2</td>
<td>21.6±2.4**</td>
<td>23.0±3.7</td>
</tr>
</tbody>
</table>

*Mean ± standard deviation.
**p<0.01, ***p<0.001; Significance by Student's t-test between male and female.
BMIs, the males were overweight and females were in the normal range when compared to the standard values of the Korean Society for the Study of Obesity (18.5 ~ 22.9: Normal, 23 ~ 24.9: Overweight, 25 or higher: Obese). Also, the figures were similar to the 2.4 and 21.4 of males and females respectively aged 19 ~ 29 as given by the Korea National Health and Nutrition Examination Survey (15).

**Intakes of sodium and potassium**

Nutrient intakes centering on the sodium and potassium of study targets are as shown in Table 2. The daily average energy intake by males was 1733.4 kcal and by females was 1570.4 kcal. As such, there was no significant difference. The daily average sodium intakes by males and females were 138.3 mEq (3.2 g) and 127.5 mEq (2.9 g) respectively. Sodium densities considering energy intakes were 82.6 mEq/1000 kcal (1.9 g/1000 kcal) and 79.3 mEq/1000 kcal (1.8 g/1000 kcal) respectively of males and females and therefore no significant difference was observed.

These results were lower than the 169.6 mEq (16) for female college students and 199.9 mEq (17) for adult males and females in rural regions. However, they were higher than 120.8 mEq (10) by female college students. The Korea National Health and Nutrition Examination Survey (15) reported that the daily sodium intakes during the 4 survey periods are 5.0 ~ 5.8 g for males and 3.6 ~ 4.6 g for females. In 1975, Korean people consumed a large amount of sodium in their diet, approximately 20 g daily. However, recent studies report a significant decrease in the sodium intakes. Even so, considering that the intakes reported by a study conducted 10 years ago (10) are not much different from the results of this study or the Korea National Health and Nutrition Examination Survey (15), attention must be given to the fact that Koreans are still consuming common salts significantly in excess of the goal intake level of 2 g/day.

The potassium intakes by the targets of this study were 43.1 mEq (1.7 g) and 49.3 mEq (1.9 g) respectively. When also considering energy intake, the potassium density of males was 25.3 mEq/1000 kcal (1.0 g/1000 kcal), which was significantly lower than the 30.5 mEq/1000 kcal (1.2 g/1000 kcal) of females. In comparison to the potassium intakes of 3.1 g and 2.4 g respectively by males and females aged 19 ~ 29 as reported by Korea National Health and Nutrition Examination Survey (15), the potassium intakes by study targets were lower. On the other hand, the intake levels were similar to the 44.2 mEq by female college students (10), the 49.56 mEq surveyed by intake record method (16) and the 46 mEq of female college students (18). It is reported that the requirement of potassium to supplement deficiencies and maintain the normal level inside the body is approximately 2 g per day. Also, in Korea, the adequate intake of potassium for adults is set at 4.7 g per day (2). Potassium intake is known to play positive roles in suppressing increases in blood pressure triggered by excessive sodium intake as well as reducing the risk of kidney stones (19). Therefore, potassium intake in this study was found to be low, and nutritional education and new guidelines may be necessary to increase the intake level.

**Serum levels of sodium and potassium**

As for the blood sodium and potassium levels in study targets shown in Table 3, serum sodium levels of males and females were, respectively, 148.2 mEq/L and 145.3 mEq/L and potassium levels were 4.9 mEq/L and 4.8 mEq/L, respectively, indicating no significant differences.

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**Table 2. Daily intakes of energy, Na and K of the subjects**

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Male (n=23)</th>
<th>Female (n=27)</th>
<th>Total (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>1733.4 ± 552.2*</td>
<td>1570.4 ± 367.0</td>
<td>1645.4 ± 463.7</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>65.7 ± 20.4</td>
<td>59.7 ± 24.1</td>
<td>62.4 ± 22.5</td>
</tr>
<tr>
<td>Lipid (g)</td>
<td>57.4 ± 20.9</td>
<td>53.2 ± 17.7</td>
<td>55.1 ± 19.2</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>233.0 ± 85.2</td>
<td>204.6 ± 49.2</td>
<td>217.7 ± 68.9</td>
</tr>
<tr>
<td>Na (mEq) (mEq/1000 kcal)</td>
<td>138.3 ± 45.0</td>
<td>127.5 ± 57.0</td>
<td>132.5 ± 51.6</td>
</tr>
<tr>
<td>K (mEq) (mEq/1000 kcal)</td>
<td>43.1 ± 12.8</td>
<td>49.3 ± 22.4</td>
<td>46.4 ± 18.7</td>
</tr>
</tbody>
</table>

*Mean ± standard deviation.
p<0.05; Significance by Student's t-test between male and female.

**Table 3. Serum levels of Na and K in the subjects**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=23)</th>
<th>Female (n=27)</th>
<th>Total (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum Na</td>
<td>148.2 ± 32.0*</td>
<td>145.3 ± 28.8</td>
<td>146.6 ± 30.0</td>
</tr>
<tr>
<td>Serum K</td>
<td>4.9 ± 0.5</td>
<td>4.8 ± 0.5</td>
<td>4.8 ± 0.5</td>
</tr>
</tbody>
</table>

*Mean ± standard deviation.
Sodium is the major positive ion of extracellular fluid with a concentration of 140~150 mEq/L. On the other hand, the sodium concentration in intracellular fluid is approximately 15 mEq/L. Also, the potassium concentration in extracellular fluid is 15 mEq/L and in intracellular fluid is 157 mEq/L (20). The serum sodium levels of the study targets were slightly higher than the normal levels of 135~145 mEq/L and potassium levels were within the normal range of 3.5~5.3 mEq/L.

**Excretions and balances of sodium and potassium**

The excretions of sodium and potassium by study targets are as shown in Table 4. The average daily sodium excretions through urine for males and females were 136.6 mEq (3.1 g) and 97.0 mEq (2.2 g), respectively, and through feces they were 2.2 mEq (0.05 g) and 2.0 mEq (0.04 g), respectively. The average daily potassium excretions for males and females through urine were 20.2 mEq (0.79 g) and 16.5 mEq (0.65 g), respectively, and through feces were 7.7 mEq (0.30 g) and 7.5 mEq (0.30 g), respectively, indicating no significant differences between the sexes. The results on the balance of sodium and potassium of the study targets are as shown in Table 5. The daily average amounts of sodium retained by males and females were 22.6 mEq and 28.5 mEq, respectively. The retention rates were 11.7% and 14.1%, and the apparent absorption rates were 98.5% and 97.8% respectively. The daily average amounts of potassium retained by males and females were 15.9 mEq and 25.9 mEq, respectively. When comparing males and females, the retention rates were 32.9% and 39.8%, and the apparent absorptions were 81.9% and 81.3%, respectively, thereby indicating no significant gender differences.

A study evaluating sodium excretions in urine reported that 198.0 mEq of sodium is excreted through the urine per day (21). Also, this study reported that daily sodium excretion amounts through urine by observed college students were 199.1 mEq by males and 174.5 mEq by females (18). In a study targeting adults (22), the amounts were reported to be 185~233 mEq, while a study on adult females in rural regions (17) reported the amount to be 169.6 mEq. In a study targeting female students (10), sodium excretion through urine was reported to be 99.8 mEq. Sodium excretion rates respond rapidly to various factors, such as sodium intake amount, kidney function and renal blood flow. In particular, sodium excretion through the urine was largely determined by the intake amount (23). In this study, the daily sodium excretions through urine were lower than the levels indicated by the previous studies. This is most likely due to the fact that salt intake of the subjects in this study was decreased. Also, we believe that accurate evaluation of excretion amount is through the state of balance based on the intake quantity. Sodium excretions through feces have been reported to be of 1~5 mEq regardless of the intake quantities (21) and the excretion amount of this study’s targets was 2.1 mEq, which was within this level.

The daily average potassium excretion through urine in this study was 18.2 mEq, which was 46.4% of the intake quantity. This result was similar to a previous study, which reported that when the daily potassium intake evaluated dietary record method by an adult female was 27.2 mEq, 49.03% of the potassium was excreted through urine (24). However, this result was lower than the 68.8% reported by a study conducted on similar method to this study in female college students (10). This could be due to lower levels of potassium intake.

### Table 4. Urinary and fecal excretions of Na and K in the subjects (mEq/day)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=23)</th>
<th>Female (n=27)</th>
<th>Total (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na Urinary excretion</td>
<td>136.6±89.4</td>
<td>97.0±72.9</td>
<td>115.2±82.5</td>
</tr>
<tr>
<td>Fecal excretion</td>
<td>2.2±2.6</td>
<td>2.0±2.2</td>
<td>2.1±2.4</td>
</tr>
<tr>
<td>K Urinary excretion</td>
<td>20.2±13.2</td>
<td>16.5±6.4</td>
<td>18.2±10.2</td>
</tr>
<tr>
<td>Fecal excretion</td>
<td>7.7±5.7</td>
<td>7.5±3.8</td>
<td>7.6±4.8</td>
</tr>
</tbody>
</table>

1) Mean±standard deviation.

### Table 5. Na and K balances of the subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=23)</th>
<th>Female (n=27)</th>
<th>Total (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na Retention (mEq/day)</td>
<td>22.6±74.2</td>
<td>28.5±72.8</td>
<td>15.1±89.0</td>
</tr>
<tr>
<td>Retention rate (%)</td>
<td>11.7±48.1</td>
<td>14.1±64.7</td>
<td>22.9±42.6</td>
</tr>
<tr>
<td>Apparent absorability (%)</td>
<td>98.5±1.7</td>
<td>97.8±3.1</td>
<td>98.1±2.5</td>
</tr>
<tr>
<td>K Retention (mEq/day)</td>
<td>15.9±17.9</td>
<td>25.9±23.9</td>
<td>21.3±21.7</td>
</tr>
<tr>
<td>Retention rate (%)</td>
<td>32.9±37.1</td>
<td>39.8±40.9</td>
<td>36.6±39.0</td>
</tr>
<tr>
<td>Apparent absorability (%)</td>
<td>81.9±13.1</td>
<td>81.3±15.6</td>
<td>81.6±14.4</td>
</tr>
</tbody>
</table>

1) Mean±standard deviation.
2) Intake = urinary excretion − fecal excretion
3) [(Intake − urinary excretion − fecal excretion)/intake] × 100
4) [(Intake − fecal excretion)/intake] × 100
Table 6. Correlation coefficients among Na and K balances of the subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dietary</th>
<th>Serum</th>
<th>Urinary</th>
<th>Fecal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Na</td>
<td>K</td>
<td>Na</td>
<td>K</td>
</tr>
<tr>
<td>Dietary</td>
<td>0.3805**</td>
<td>-0.0009</td>
<td>0.0206</td>
<td>0.0045</td>
</tr>
<tr>
<td>Serum</td>
<td>0.1836</td>
<td>-0.0111</td>
<td>0.0714</td>
<td>-0.0982</td>
</tr>
<tr>
<td>Urinary</td>
<td>0.0276</td>
<td>0.1146</td>
<td>0.0735</td>
<td>0.5081***</td>
</tr>
<tr>
<td>Fecal</td>
<td>-0.0773</td>
<td>0.0947</td>
<td>0.0732</td>
<td>0.2850</td>
</tr>
</tbody>
</table>

*p<0.05, **p<0.01, ***p<0.001; Significance by Pearson's correlation-test.

Table 7. Correlation coefficients among Na and K balances, anthropometric indices, and nutrient intakes of the subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Energy</th>
<th>Protein</th>
<th>Lipid</th>
<th>Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietary</td>
<td>0.5032***</td>
<td>0.3807***</td>
<td>0.3342***</td>
<td>0.5072***</td>
</tr>
<tr>
<td>Serum</td>
<td>0.6843***</td>
<td>0.7132***</td>
<td>0.5617***</td>
<td>0.5654***</td>
</tr>
<tr>
<td>Urinary</td>
<td>-0.1066</td>
<td>-0.1013</td>
<td>-0.0996</td>
<td>-0.0805</td>
</tr>
<tr>
<td>Fecal</td>
<td>0.0489</td>
<td>0.0321</td>
<td>-0.0018</td>
<td>0.0699</td>
</tr>
</tbody>
</table>

*p<0.05, **p<0.01, ***p<0.001; Significance by Pearson's correlation-test.

by the targets of this study as discussed earlier.

Relation among sodium balance, potassium balance, and nutrient intakes

The relations among sodium balance, potassium balance, and nutrient intakes are as shown in Tables 6 and 7. The intakes of sodium and potassium, sodium and potassium excretions through urine, sodium excretions through urine and feces, and sodium and potassium excretions through feces indicated a significantly positive correlation. While the sodium and potassium intakes indicated significant positive correlations with nutrient intakes, serum levels and excretions through urine and feces did not display significant correlations with nutrient intakes. It is reported that since potassium can suppress increases in blood pressure caused by excessive sodium intake, the potassium should increase as the sodium intake increases (7) and that there is a significant correlation between potassium excretion and potassium intake (2). In this study, sodium intake did not indicate a directly significant correlation with potassium excretion. However, in both urine and feces, the excretions of sodium and potassium displayed significant correlations to indicate a metabolic relation between them. In addition, it is indirectly indicated that an increase in potassium intake is necessary in order to accelerate sodium excretion while sodium intake level is still high. In particular, considering the low potassium intakes and excretions of this study targets while the sodium intakes exceeded the daily goal intake, an effort is necessary to increase potassium intake through daily diet.

The present study is limited by its participant size, so that it is too small to be considered an accurate reflection of the general population. In addition, the current study did not include markers to check 24-hr collections of urine and feces of the participants. Therefore, further studies of sodium and potassium balances within larger samples of the Korean population are needed.

REFERENCES

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