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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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85% and 77～90% of the absorbed potassium is filtered through kidneys. Of the filtered potassium, 70～80% is reabsorbed by the proximal tubules with the remainder being excreted in the urine (2). A previous study conducted on the balance of sodium and potassium in 20 female college students (10) reported that the retention and apparent absorption of sodium were 13.2% and 96.3%, respectively, and of potassium were 8.7% and 80.1%, respectively, which were similar to the results of other studies. This study also reported that excretion through urine was a sensitive index to estimate intake.

As such, while sodium intake is still high in Korea, a study on sodium-potassium balance based on sodium intake through ordinary diet is necessary. As for potassium, it has close metabolic relevance to sodium. However, most domestic studies to date on sodium and potassium have focused on their relevance to the risk of hypertension (11-14). Therefore, in this study, we analyzed sodium and potassium intakes, blood levels and excretions by young adult males and females with ordinary dietary intakes and thereby evaluate their state of balance, and then examine the relevance of each factor.

MATERIALS AND METHODS

Subjects

This study was conducted on 50 college students aged 20～28 (23 males and 27 females) from November 1, 2007 to March 31, 2008 using physical measurements, dietary intake recordings, blood sampling and urine · feces collection. All participants, who were healthy without any disease and who did not take any medications, gave consent to participate in this study.

Anthropometric measurements

Height was measured without shoes by using a height measuring instrument. Weight was measured with light clothes on by using InBody (InBody720, Biospace Co., Ltd., Seoul, Korea). Height and weight were measured twice and the average value was taken.

Dietary intakes

As for the dietary intake survey, the subjects were educated and asked to weigh and record all types of foods taken for 3 full days. Breakfast, lunch, dinner, and snacks were included in this survey as well as the quantities and types of each food material used. Dietary nutrient intakes were analyzed using CAN-Pro 3.0 (Korean Nutrition Society, Seoul, Korea).

Sampling and analysis of urine and feces

On the last day of the dietary intake survey, urines and feces were collected over 24 hrs using plastic urine sampling bottle 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 create test fluid. Then, using the ICP-AES (Thermoelemental 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 water and all moisture was removed using a dryer.

Statistical analysis

The means and standard deviations of all results obtained during the experiment were calculated using the SAS program (ver. 8.1). For differences in analysis results per male and female, unpaired Student's t-test was used. As for the relevance between each factor, the evaluation was conducted using the Pearson's correlation coefficient (r) and its significance verification. The significances 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 55.8 kg and body mass index (BMI) were 24.6 kg/m^2 and 21.6 kg/m^2, 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 55.3 kg for females aged 19～29 as described by the Korea National Health and Nutrition Examination Survey 2007 (15). As for the

Table 1. General characteristics of the subjects

Variable	Male (n=23)	Female (n=27)	Total (n=50)
Age (years)	24.7±2.4[1)]	22.8±0.7**	23.7±1.9
Height (cm)	173.2±4.1	161.1±3.8***	166.6±7.2
Weight (kg)	73.6±12.7	55.8±6.6***	64.0±13.3
Body mass index (kg/m^2)	24.6±4.2	21.6±2.4**	23.0±3.7

[1)]Mean±standard deviation.
**$p<0.01$, ***$p<0.001$; Significance by Student's t-test between male and female.

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

Nutrients	Male (n=23)	Female (n=27)	Total (n=50)
Energy (kcal)	1733.4±552.1[1)]	1570.4±367.0	1645.4±463.7
Protein (g)	65.7±20.4	59.7±24.1	62.4±22.5
Lipid (g)	57.4±20.9	53.2±17.7	55.1±19.2
Carbohydrate (g)	233.0±85.2	204.6±49.2	217.7±68.9
Na (mEq)	138.3±45.0	127.5±57.0	132.5±51.6
(mEq/1000 kcal)	82.6±25.2	79.3±23.4	80.9±24.0
K (mEq)	43.1±12.8	49.3±22.4	46.4±18.7
(mEq/1000 kcal)	25.3±4.1	30.5±9.9*	28.1±8.2

[1)]Mean±standard deviation.
*$p<0.05$; 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 24.1 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.

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

(mEq/L)

Variable	Male (n=23)	Female (n=27)	Total (n=50)
Serum Na	148.2±32.0[1)]	145.3±28.8	146.6±30.0
Serum K	4.9±0.5	4.8±0.5	4.8±0.5

[1)]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)

Variable		Male (n=23)	Female (n=27)	Total (n=50)
Na	Urinary excretion	136.6±89.4[1)]	97.0±72.9	115.2±82.5
	Fecal excretion	2.2±2.6	2.0±2.2	2.1±2.4
K	Urinary excretion	20.2±13.2	16.5±6.4	18.2±10.2
	Fecal excretion	7.7±5.7	7.5±3.8	7.6±4.8

[1)]Mean±standard deviation.

Table 5. Na and K balances of the subjects

Variable		Male (n=23)	Female (n=27)	Total (n=50)
Na	Retention (mEq/day)[2)]	22.6±74.2[1)]	28.5±72.8	15.1±89.0
	Retention rate (%)[3)]	11.7±48.1	14.1±64.7	22.9±42.6
	Apparent absorbability (%)[4)]	98.5±1.7	97.8±3.1	98.1±2.5
K	Retention (mEq/day)	15.9±17.9	25.9±23.9	21.3±21.7
	Retention rate (%)	32.9±37.1	39.8±40.9	36.6±39.0
	Apparent absorbability (%)	81.9±13.1	81.3±15.6	81.6±14.4

[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

Variable		Dietary		Serum		Urinary		Fecal	
		Na	K	Na	K	Na	K	Na	K
Dietary	Na								
	K	0.3805**							
Serum	Na	0.1836	-0.0009						
	K	0.0206	0.0255	0.0045					
Urinary	Na	0.0276	-0.0111	0.0714	-0.0982				
	K	-0.0737	-0.0055	0.1146	0.0375	0.5081***			
Fecal	Na	-0.0773	-0.1454	0.0947	0.0732	0.2850*	0.2780		
	K	0.1774	0.1323	0.0455	0.1006	0.0951	0.1291	0.2855*	

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

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

Variable		Energy	Protein	Lipid	Carbohydrate
Dietary	Na	0.5032***	0.3807**	0.3342*	0.5072***
	K	0.6843***	0.7132***	0.5617***	0.5654***
Serum	Na	-0.1066	-0.1013	-0.0996	-0.0805
	K	0.0489	0.0321	-0.0018	0.0699
Urinary	Na	0.1810	0.1982	0.1520	0.1549
	K	0.0727	-0.0399	0.1087	0.0730
Fecal	Na	-0.0494	-0.0878	-0.1253	0.0375
	K	0.0130	-0.0009	-0.0510	0.0649

*$p<0.05$, **$p<0.01$, ***$p<0.001$; 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.

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