Characteristics of Urine Sodium and Potassium after Oral Ingestion of Solutions Containing Sodium and Potassium Which Is Isotonic to the Physiological Saline
—A Quantitative Study—

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Summary The effects of orally ingesting 500 mL of four kinds of test solutions that were isotonic to physiological saline (i.e., containing sodium (Na) and potassium (K) as chloride with Na/K molar ratios of 1, 2, 3 and 4) on urine flow, Na and K excretions from Japanese male students were investigated. The subjects assembled at the National Institute of Nutrition the day before the oral ingestions, which were conducted three times for each subject. They were permitted to eat freely until 8:00 pm, and then the intake of food and drinks except tap water was prohibited until 10:00 pm. After that, no food or drinks except the test solution used, were permitted to be ingested until the end of the final collection of urine. Subjects were woken up at 7:00 am the next morning, at which time they emptied their bladder. At 8:00 am, after sampling control urine before ingestion, they ingested 500 mL of water, the physiological saline or one of the test solutions. Urine was collected every 30 min for 4 h after ingestion. Urine flow was significantly higher for those who drank solutions Na/K=1 and 2 than those who drank the saline (paired t-test), but that for those who drank solutions Na/K=3 and 4 was not significantly higher. For those who drank solution Na/K=2, urine Na was significantly higher than that of those who drank the saline 30 to 60 min after ingestion. An increase in urine flow after K ingestion may be an essential factor for K-induced Na uraesi.

Key Words urine flow, urine sodium (Na), urine potassium (K), Na ingestion, K ingestion

Sodium (Na), a monovalent cation, is one of the essential minerals that act to maintain the osmotic pressure of extracellular space (1). On the other hand, potassium (K) is another mineral for maintaining intracellular osmolarity (2). To maintain this gradient of two minerals, an active transport system called the Na/K pump plays the most important role at the border between the two areas, the cell membrane.

Most (98–100%) of the Na ingested is absorbed, and nearly the same amount as ingested is excreted via urination (3). However, renal handling of the ingested Na seems not to be so rapid as to excrete all of the Na ingested within 4 h (4). On the other hand, dietary K increases during urine sodium excretion (5).

Oral ingestion of 500 mL of physiological saline (0.9% sodium chloride solution, “0.9% Saline”) induced uraesi of not only Na, but also K with a slight increase in urine flow (4). On the other hand, the oral ingestion of 500 mL of pure water (“Water”) induced uraesi without eminent Na loss as the result of diluting the urine (4). Oral ingestion of K leads to the uraesi of not only K itself, but also that of Na (2). However, the effects of oral K ingestion on the urinary excretion of K and Na have not been fully understood (6). A quantitative analysis of this effect is needed to understand the dose response of this effect.

The purpose of this study is to investigate the dose effects of the oral administration of K on the urine excretion of Na. Test solutions were selected to contain sodium and potassium with the same osmolarity as that of 0.9% saline so as to avoid the effects of osmolarity. The test solutions were therefore designed so as to replace some part of sodium for potassium in the 0.9% Saline.

SUBJECTS AND METHODS

The subjects were 31 male medical students of a medical school, who were willing to participate this experiment. The experiment was performed from October 1979 to January 1980 when there was no ethical committee at the National Institute of Health. The protocol of this experiment was designed according to the spirit of the Helsinki Declaration (Fig. 1). Every subject took part in the experiments three times, with an interval of more than 1 wk for each trial. After finishing supper, the subjects went to the metabolic ward of the National Institute of Nutrition by 8:00 pm in the evening on the day prior to the loading test, and then did not eat anything until the end of the experiment; they were allowed to consume pure water. Skinfold thickness (subscapula and upper arm back) was measured by Eiken callipers before going to bed at 10:00 pm. After this, they did not drink anything except the test
solution until the end of the experiment. At 7:00 am the next morning, the subjects got up, emptied their bladders and had their weight, height and blood pressure measured. At 8:00 am, a urine sample was collected before loading. Then each subject drank 500 mL of one of the test solutions listed in Table 1. After that, they urinated every 30 min for 240 min. All of the subjects took 0.9% Saline, Water or one of the solutions containing Na and K with the same osmolarity as 0.9% Saline.

Urine Na and K were measured using an atomic absorption spectrophotometer (Varian AA=5, Australia). Statistical analyses were carried out using StatViewJ5.0. Data were indicated as mean±SD. Statistics used were independent or dependent t-test after ANOVA (two-way repeated-measures). A p value of <0.05 was
Urine Na and K after Oral Ingestion of Na and K

Fig. 3. Urine flow and urine excretions of sodium (Na) and potassium (K) after the ingestion of 500 mL of the control (0.9% Saline) and the test solutions (Test solution) for which the total molar concentrations of Na and K were isomolar to that of physiological (0.9%) Saline, of which the molar ratios were 4, 3, 2 and 1. *p<0.05, **p<0.01 compared with the respective 0.9% Saline experiment (paired-t test).
RESULTS

Control experiments

The results of urine flow and urine Na and K excretion during the two control experiments, in which all subjects were given both 500 mL of the physiological saline (0.9% sodium chloride solution: 0.9% Saline) and pure water (Water) (n=31), are shown in Fig. 2. Eminent water uresis occurred from 30 to 150 min after the ingestion of Water. However, urine Na was higher in Saline than in Water from 60 min after ingestion to the end of the experiment. Urine K in Water was higher than in Saline from 30 to 60 min, lower from 120 to 150 min and lower from 210 to 240 min after ingestion.

Experiments with the solutions containing Na and K isotonic to 0.9% Saline

The results of urine flow, and Na and K excretion after the ingestion of the solutions containing Na and K (Test solution) were compared to those for 0.9% Saline from the same subjects (Fig. 3). Urine flow was higher for the Test solutions with a Na/K ratios of 1 and 2 when compared with that of the respective 0.9% Saline. Urine Na was higher only in the Test solution with a Na/K ratio of 2 from 30 to 60 min after ingestion when compared with that of the respective 0.9% Saline. Urine K was higher in part only for the Test solutions with Na/K ratios of 1, 2 and 3 when compared with that of the respective 0.9% Saline.

The relationships between ingestion and total urine excretion at 4 h after the ingestion of both Na and K are shown in Fig. 4. There were no linear relationships between the dose ingested and excretion of Na and K after 4 h.

The subjects who ingested the Test solution with a Na/K ratio of 2 excreted the most urine Na and K, on average, among the four Test solutions, but the difference was not significant. Almost all of the Na and K ingested was excreted through the urine 4 h after ingestion of the solution.

Fig. 4. Relationship between ingested and excreted Na and K. *p<0.05, **p<0.01 (independent t-test).

DISCUSSION

To avoid the osmolar effects of drinking solutions in these experiments, all of the test solutions were isosmolar. Compared to Water, a significant K uresis appeared with the ingestion of each Test solution. However, eminent water uresis accompanied by the uresis of Na and K was observed only when the Test solutions with Na/K ratios of 1 and 2 were ingested. In these cases, almost all of the Na ingested was excreted through the urine within 4 h after ingestion (Fig. 4). On the contrary, in the rest of the Test solutions as well as 0.9% Saline, some of the ingested Na still remained in the body 4 h after ingestion. Na uresis associated with K uresis may need water uresis.

In case of water uresis by Water, as shown in Fig. 2, urine K excretion increased with the onset of the water uresis without being accompanied by the eminent Na uresis. Therefore, the nature of these two forms of uresis seems to be different, especially in the renal handling of Na and K or water.

In comparison with Na uresis associated with K and water uresis for the Test solutions with Na/K ratios of 1 and 2, the latter (Na/K=2) seems to be more eminent than the former (Na/K=1). The contents of Na and K, as well as personal variations, may affect these results. Further studies are needed to identify the mechanisms of these phenomena.

In conclusion, urine Na was increased after ingesting 500 mL of isotonic K-supplemented solution with a Na/K ratio of 2 within 30 to 60 min after ingestion. An increase in urine flow after K ingestion may be an essential factor for K-induced Na uresis.

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REFERENCES