AVERAGE URINARY EXCRETION OF SODIUM IN 24 HOURS CAN BE ESTIMATED FROM A SPOT-URINE SPECIMEN

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We assessed to what extent sodium intake can be estimated from the sodium content of a spot-urine specimen (spot-UNa) collected within 4 hours after the first voiding upon awakening but before breakfast. Subjects were asked to collect spot-urine and 24-hour urine specimens other than the spot-urine for a 3-day period, either successively or intermittently. The coefficient of correlation between spot-UNa and urinary excretion of sodium in 24 hours (24-h UNa) collected on the first day was 0.47. When the coefficient of the variation of creatinine excretion in the spot-urine was above 20%, the sample was discarded as the "outlier", and in this case the coefficient of correlation was 0.725. A marked fluctuation of creatinine excretion in spot-urine was considered to represent technical errors at the time of the spot-urine collection. The coefficient of variation of intra-individual 24-h UNa exceeded 20%, suggesting that a single determination of 24-h UNa does not represent the individual average of daily urinary excretion of sodium.

It is concluded that the determination of a substantial number of spot-urine specimens to estimate daily salt ingestion of a given subject may be more reliable than a single determination of 24-h UNa, if the "outlier" of creatinine excretion in spot-urine specimen is excluded from the determination of spot-UNa.

The average urinary excretion of sodium in 24 hours by the Japanese subjects investigated here was 218 ± 67 mEq.

In epidemiological surveys, it has been demonstrated that there is a positive correlation between the average daily salt intake and the prevalence of hypertension or average blood pressure; populations with higher salt consumption show higher blood pressure levels than those with lower salt consumption. Populations with very low salt intake show no increase of blood pressure with age.

Sasaki analyzed data from the various populations throughout the world, and the coefficient of the correlation between the average systolic blood pressure and the average estimated salt intake of men in their fifties was approximately 0.84. However, only a few reports have

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and physiological interpretations based on a single determination should be made with caution.

We studied whether or not the amount of sodium in fractional urine specimens could be used to estimate the urinary excretion of sodium. Here, we tried to utilize the spot-urine specimens for estimating the average urinary excretion of sodium in 24 hours. The study was based on one protocol involving 8 districts throughout Japan.

**MATERIALS AND METHODS**

The participants in the present study were 91 clinically healthy Japanese men and 151 clinically healthy Japanese women from the cities of Sapporo, Akita, Sendai, Kyoto, Osaka and Fukuoka and the towns of Yuwa and Hisayama, taking their ordinary house diet. Their ages ranged from 20 to 63 with an average and standard deviation of 37 ± 14 years. Their blood pressure was below 140 in systole and 90 mmHg in diastole and they had neither proteinuria nor glucosuria.

The protocol is illustrated in Fig. 1. They were asked to discard urine voided at approximately 8:00 a.m. and to collect all urine voided during the subsequent full day until approximately 8:00 a.m. the next morning. This approximate one-day urine was considered to be a 24-hour urine sample. Urine collected at approximately 8:00 a.m., before breakfast but after the urine collection at the rising time the next morning, was also used as a spot-urine specimen. Spot-urine specimens and the rest of the 24-hour urine were collected separately. The starting and closing time of each spot-urine specimen and the starting time of the 24-hour urine collection were recorded by each person. The collection was made for a 3-day period, either successively or intermittently, in spring or fall, except on weekends and holidays. Snacks and beverages were prohibited after 11:00 p.m. Spot-urine specimens collected over a time interval of less than 4 hours and containing more than 20 ml/h were accepted for the study.

In 3 subjects, urine was collected for 21 to 25 days to determine the intra-individual variations in urinary excretion of sodium and creatinine and to calculate the intra-individual coefficient of correlation between spot-urine specimens and 24-hour urine collection for the excretion of sodium.

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TABLE I  RELATIONSHIP OF INTRA-INDIVIDUAL VARIATION BETWEEN URINARY EXCRETION OF SODIUM IN 24 HOURS (24-h UNa) AND THAT OF CREATinine IN 24 HOURS (24-h Ucreat)

\[
\begin{array}{cccc}
\text{Intra-individual SD of 24-h Ucreat (\%)} & \text{any} & 20 & 10 & 8 \\
\text{No. of persons} & 117 & 102 & 72 & 55 \\
\text{Intra-individual variation of 24-h UNa} & 522 & 501 & 475 & 518 \\
\text{Intra-individual SD of 24-h UNa (\%)} & 22.8 & 22.4 & 21.8 & 22.8 \\
\end{array}
\]

Intra-individual standard deviation (SD): the square root of the intra-individual variation

TABLE II  INTRA-INDIVIDUAL VARIATION OF URINARY EXCRETION OF SODIUM AND CREATinine IN SPOT-URINE SPECIMEN AND IN 24-OURN URINE COLLECTION

\[
\begin{array}{ccc}
\text{Spot-urine} & \text{24-hour urine} & \text{Ratio of variation} \\
\text{Variation} & \text{SD (\%)} & \text{Variation} & \text{SD (\%)} & \\
\text{UNa} & 1230 & 35.1 & 574 & 24.0 & 2.14 \\
\text{Ucreat} & 145 & 12.0 & 118 & 10.9 & 1.23 \\
\end{array}
\]

UNa = urinary sodium excretion; Ucreat = urinary creatinine excretion

Analysis of urine collected for a 3-day period from 59 persons whose intra-individual standard deviation of creatinine excretion in spot-urine specimens was below 20%.

Variation = intra-individual variation, SD = intra-individual standard deviation (the square root of variation)

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Fig. 3. The correlation coefficients between spot-urine specimen and 24-hour urine collection for excretion of sodium for 3 different situations.

Group (A) consists of the first urine sample for all 242 persons; Group (B), the average of the 3-day urine collected per person for 117; Group (C), urine samples for 59 with an intra-individual standard deviation of spot-urine specimen for excretion of creatinine limited within 20%.
Urinary concentration of sodium was measured by flame photometry with lithium as the internal standard (Hitachi Flame Photometer 205D) and urinary concentration of creatinine by the Jaffe reaction (Beckman Creatinine Analyzer 2).

The intra-individual variation for each person who completed the 3-day urine collection was calculated by taking the average for each person as 100%. The intra-individual standard deviation (SD) was calculated as the square root of the intra-individual variation.

RESULTS

Intra-individual urinary excretion of sodium in 24 hours (24-h UNa) in 3 persons varied widely as shown in Fig. 2. The coefficient of variation (standard deviation divided by the mean value) for each person, however, was 25, 26 and 27%, respectively. Correlation coefficients between urinary excretion of sodium in spot-urine specimens (spot-UNa) and 24-h UNa in each of 3 persons were 0.780, 0.825 and 0.758. The coefficients of variation of urinary excretion of creatinine in 24 hours (24-h Ucreat) for each person were 10.0, 11.1 and 12.2%, respectively.

The protocol was followed by 117 men and women for 3 days, by 89 for 2 days and by 36 for one day. When the intra-individual SD of 24-h Ucreat in 117 persons completing the 3-day urine collection was limited within 20, 10 or 8%, as shown in Table I, the intra-individual SD of 24-h UNa was 22.4, 21.8 or 22.8%, respectively. There was no relationship between the intra-individual variation in 24-h UNa and that in 24-h Ucreat.

The intra-individual SDs of spot-UNa and of creatinine in spot-urine specimens (spot-Ucreat) from 117 persons were 40.6 and 32.4% on the average, respectively, whereas those of 24-h UNa and of 24-h Ucreat were 22.8 and 13.2%, respectively. Although urinary excretion of creatinine is considered rather stable with respect to intra-individual variation, the ratio of the intra-individual variation between spot-Ucreat and 24-h Ucreat was as high as 6.03. It was not reasonable to expect such a marked fluctuation in urinary excretion of creatinine, so technical errors may have occurred at the time of the
collection of spot-urine specimens.

When persons with an individual SD of spot-Ucreat exceeding 20% were excluded as the “outlier”, the ratio of the variation between spot-Ucreat and 24-h Ucreat was 1.23, although the number of persons was not reduced to 59, as shown in Table II.

The correlation coefficients between spot-UNa and 24-h UNa for 3 different situations are shown in Fig. 3: group (A) consists of the first calculation for all 242 persons; group (B), the average of the 3-day urine collected per person for 117 and group (C), the sample for 59 persons with an intra-individual SD of spot-Ucreat limited within 20%. The correlation coefficient for the 59 was 0.725. No change was seen in the correlation coefficient when the intra-individual SD of spot-Ucreat was limited to within 25 or 30%, and also when the intra-individual SD of 24-h Ucreat was within 20%. Spot-UNa was also expressed per gram of creatinine in order to assess the correlation with 24-h UNa. However, the correlation coefficients did not change: 0.432 for 242, 0.568 for 117 and 0.566 for 59 persons, respectively.

Figure 4 shows the correlation between spot-UNa and 24-h UNa for 59 persons. The shaded area indicates the 99% confidence limits of the regression line. Thus, the average 24-h UNa in a given person whose spot-UNa is 10 mEq/h can be estimated to range from 220 to 260 mEq from the correlation and 99% confidence limits of the regression line shown in Fig. 3.

Figure 5 shows the confidence limits of the daily urinary excretion of sodium estimated from the value of spot-UNa. The average 24-h UNa in 59 persons was 218 ± 67 mEq (12.7 ± 3.9 g per day of salt) and the confidence limit was the smallest at this point. It was gradually extended together with the increase in the distance from the average. If the estimated excretion of salt is 13 g/day or 20 g/day, the 95% confidence interval would be 13 ± 0.7 g/day or 20 ± 2.0 g/day, respectively, as shown in Fig. 5.

**DISCUSSION**

Urinary excretion of sodium in 24 hours has been generally utilized in estimating dietary sodium (or salt) intake. As shown in Fig. 1, however, the intra-individual variation varied widely, even though the activity and the mealtime of the diet were restricted as shown in our protocol. Previous studies reported that the intra-individual standard deviation (the coefficient of variation) of urinary creatinine excretion was between 10 and 16%.

In the present study, it was also 10, 11 and 12% in 3 individuals, respectively. Even when the intra-individual SD of 24-h Ucreat was limited to within 20, 10 or 8%, there was little change in the intra-individual SD of 24-h UNa. No relationship was observed between the intra-individual variation in 24-h Ucreat and that in 24-h UNa. Therefore, a wide intra-individual variation in 24-h UNa did not represent technical error but rather, physiological variation, and it seems to be one of the inevitable factors in estimating the urinary excretion of sodium. These results suggest that a single determination of 24-h UNa does not represent the individual average of daily urinary excretion of sodium, as has already been reported.

Liu et al. proposed that 14 collections of 24-h urine are necessary to limit the error in the correlation between the true mean 24-h urinary sodium and a variable of interest to less than 10% under the cited circumstances. Sequential 24-h urine collection, however, are extremely difficult and the application of this technique to a large number of clinical trials or to an epidemiological survey is not practical. In the present study, we eliminated samples from those persons with an intra-individual SD of spot-Ucreat exceeding 20%. As a result, the ratio of variation between spot-Ucreat and 24-h Ucreat was 1.23 and the correlation coefficient between spot-UNa and 24-h UNa was 0.725. However, the number of persons reduced to 59. When spot-UNa is expressed in terms of grams of creatinine in order to assess the correlation with 24-h UNa, the technical errors are not included at the time of the collection of spot-urine specimens. Nevertheless, the correlation coefficients did not change: 0.432 for 242, 0.568 for 117 and 0.566 for 59 persons, respectively. These results suggest that possible technical errors at the time of the spot-urine collection were almost excluded by limiting the variation in spot-Ucreat.

The average urinary excretion of sodium in 24 hours was 218 ± 67 mEq for 59 persons who collected urine samples for a 3-day period and whose intra-individual SD of spot-Ucreat did not exceed 20%. They were all clinically healthy and were studied only in spring and fall when there was no excess sweating. Therefore, the kidneys were considered to be the main route for excretion of sodium and the average salt intake for the Japanese observed in the present study can

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be estimated to be approximately 13 g/day. This is somewhat lower than that in the previous report\textsuperscript{7} It will be necessary to perform a more extensive epidemiological survey to estimate the average daily salt intake for the Japanese as recently they are occasionally consuming a Western-type diet. If a substantial number of spot-urine specimens is obtained, the average excretion of sodium in such a specimen will be able to be calculated and then the range of daily sodium intake will be estimated for a given person. It is more feasible to collect spot-urine specimens sequentially than to obtain either nocturnal\textsuperscript{12,18,19} or 24-hour urine collections.

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