Relationship between Twenty-four Hour Urinary Creatinine Excretion and Weight, or Weight and Height of Japanese Children

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Summary Twenty-four hour (24-h) urinary creatinine excretion was measured and correlated with anthropometric measurements (height, weight, skinfold thickness, and arm muscle area (AMA)) in 119 healthy Japanese children, aged 2 to 18 years. The results indicated highly significant correlations between creatinine excretion and age (r=0.88 for boys, 0.90 for girls), height (r=0.91, 0.88), weight (r=0.96, 0.94), and AMA (r=0.91, 0.70). In the multiple regression estimation, weight alone, or weight and height, accounted for most of the variation in 24-h creatinine excretion (r²=0.93 for boys, 0.89 for girls), and the addition of other variables did not further improve the estimation.

Key Words growth, creatinine excretion, Japanese children, height, weight, skinfold, arm muscle area

The 24-hour (24-h) urine has been collected to evaluate urinary excretion of various electrolytes and hormone metabolites both in clinical settings and in the field. Particularly in relation to the epidemiological importance of high sodium intake as a risk factor in developing hypertension, 24-h urine is commonly used to estimate sodium intake (1). However, complete 24-h urine collection is difficult, especially in active children. Although the reliability of 24-h urine collection depends on completeness, there have not been any objective criteria to evaluate it. At most, hospitalization and strict vigilance have been recommended in clinical settings, while in the field only careful interviews have been used. Recently, Kawasaki et al. (2) have developed an equation to predict adult 24-h urinary creatinine based on age, weight, and height. Using this equation, the completeness of
urine collection can be evaluated by representing the actual excretion as a ratio of estimated excretion. However, Kawasaki's equation can be applied only to adults, and no such equations have been developed for children.

Therefore, in the present paper, the authors intended to develop a method to evaluate the completeness of urine collection in children, and tried to estimate 24-h creatinine excretion using anthropometric variables (height, weight, skinfold thickness, and arm muscle area) in a group of normal Japanese children.

SUBJECTS AND METHODS

One hundred and nineteen normal Japanese children living with their parents

Fig. 1. Height versus age: individual values in the present study are compared with cross-sectional standards (10th, 50th, and 90th percentiles) of Japanese infants (3), and school children and/or students (4).

Fig. 2. Weight versus age: individual values in the present study are compared with cross-sectional standards (10th, 50th, and 90th percentiles) of Japanese infants (3), and school children and/or students (4).
volunteered to provide 24-h urine specimens. All children were healthy, fully active, and well nourished. The height and weight of each subject were compared to the Japanese standards in children (3, 4) (Figs. 1 and 2). The children that fell in the normal range (from the 10th to 90th percentile) of height and weight amounted to 86.6% and 88.2%, respectively. All children and their supervisors (classroom teachers and mothers) were informed of the purpose of the study and the method of collection. No restrictions were placed on the children’s activities or diet on the day of collection. Each child was provided with 4 or 6 500-ml polyethylene bottles, which contained 2.5 ml of 1% NaN₃ as a preservative. The 24-h collection started and ceased at 8 a.m. from one weekday to the next from November 1984 to February 1985. The time of each urination was recorded by a subject or a supervisor. Any specimen known to be incomplete was so marked by the child or supervisor or staff and was discarded. On the day collection was completed, samples from each subject were placed into 10-ml sample tubes and stored at −30°C until analysis. Urinary creatinine was determined by the Jaffe reaction (5).

Anthropometry was carried out on each child on the day of urine collection. Measurements included height and weight for all children, and midarm circumference and skinfold thickness at the triceps and subscapular sites for children aged 8 years and older. Height was measured to the nearest mm using a stadiometer. Weight was measured in the subjects’ underwear to the nearest 0.1 kg. Midarm circumference (MAC) was measured using a plastic tape. Skinfold thickness at the triceps and subscapular sites (SFT and SFS, respectively) was measured on the left side of the body using a Harpenden caliper. Measurements of MAC and skinfold thickness were made by the same trained worker.

Arm muscle area (AMA) was calculated using the following formulas:

\[
\text{Arm diameter} = \frac{\text{MAC}}{\pi} - \text{SFT}
\]

\[
\text{AMA} = \frac{\pi}{4} \times (\text{arm diameter})^2.
\]

The percentage of fat to weight (FAT) was estimated using the following formula (6, 7):

\[
\text{FAT(\%)} = \left(\frac{4.57}{\text{body density}} - 4.142\right) \times 100
\]

where

\[
\text{body density (g/cm}^3) = 1.0913 - 0.00116 \times (\text{SFT + SFS in mm}) \text{ (for males)};
\]

\[
= 1.0897 - 0.00113 \times (\text{SFT + SFS in mm}) \text{ (for females)}.
\]

Fat-free mass (FFM) was calculated by subtracting fat from weight:

\[
\text{FFM(kg)} = (1 - \text{FAT/100}) \times \text{weight}.
\]

RESULTS

General data on the present study population are presented in Table 1.
Table 1. Urinary excretion of creatinine and anthropometric measurements (Means±SD).

| Boys age | n  | CRD\(^a\) (mg) | Height (cm) | Weight (kg) | SFT\(^b\) (mm) | SFS\(^c\) (mm) | AMA\(^d\) (mm\(^2\)) | FAT\(^e\) (%) | FFM\(^f\) (kg) |
|----------|----|----------------|-------------|-------------|----------------|----------------|-------------------|------------|--------------|
| 2–4      | 6  | 234±50         | 96.0±7.2    | 14.9±2.3    |                |                |                   |            |              |
| 8        | 7  | 586±87         | 126.5±5.2   | 24.8±1.5    | 8.3±1.7        | 5.4±1.0        | 2,070±150        | 9.3±1.1    | 22.5±1.5    |
| 9–10     | 14 | 729±112        | 136.6±5.4   | 32.3±4.7    | 9.5±2.4        | 6.5±2.5        | 2,529±464        | 10.3±2.0   | 28.9±3.8    |
| 11–12    | 13 | 846±150        | 144.5±6.2   | 36.1±5.3    | 9.2±2.5        | 6.4±2.4        | 2,560±383        | 10.2±2.0   | 32.4±4.6    |
| 13–15    | 14 | 1,532±339      | 165.1±9.8   | 54.3±9.5    | 7.5±2.8        | 8.2±3.9        | 3,941±838        | 10.2±2.8   | 48.9±7.9    |
| 16–18    | 11 | 1,690±216      | 168.7±7.1   | 56.7±5.9    | 6.3±1.2        | 7.3±1.0        | 4,379±268        | 9.3±0.7    | 51.4±5.3    |

| Girls age | n  | CRD\(^a\) (mg) | Height (cm) | Weight (kg) | SFT\(^b\) (mm) | SFS\(^c\) (mm) | AMA\(^d\) (mm\(^2\)) | FAT\(^e\) (%) | FFM\(^f\) (kg) |
|-----------|----|----------------|-------------|-------------|----------------|----------------|-------------------|------------|--------------|
| 1–4       | 5  | 182±51         | 89.4±8.1    | 12.3±2.2    |                |                |                   |            |              |
| 8         | 5  | 486±116        | 126.6±6.1   | 25.0±3.9    | 8.8±1.0        | 5.5±0.6        | 2,195±358        | 11.1±0.7   | 22.2±3.3    |
| 9–10      | 9  | 566±76         | 133.4±4.2   | 29.2±3.5    | 9.9±2.5        | 7.0±1.3        | 2,256±283        | 12.4±1.7   | 25.6±2.9    |
| 11–12     | 10 | 768±231        | 146.9±5.7   | 37.7±7.7    | 11.2±3.4       | 9.0±4.1        | 2,544±615        | 14.0±3.6   | 32.2±5.4    |
| 13–15     | 14 | 1,110±108      | 155.3±7.6   | 49.8±6.2    | 14.2±2.9       | 12.2±3.2       | 2,791±266        | 17.1±2.7   | 41.2±4.7    |
| 16–18     | 11 | 1,189±174      | 158.3±3.9   | 54.9±6.7    | 14.4±3.5       | 13.0±4.3       | 3,685±670        | 17.6±3.8   | 45.1±4.2    |

\(^a\)Twenty-four hour urinary creatinine excretion. \(^b\)Triceps skinfold thickness. \(^c\)Subscapular skinfold thickness. \(^d\)Arm muscle area. \(^e\)Percentage of fat to weight (FAT) was estimated using the formulas of Brozek \textit{et al.} (6) and Nagamine and Suzuki (7). \(^f\)Fat-free mass (FFM) was calculated by subtracting fat from weight.
Fig. 3. 24-h creatinine excretion in relation to age, height, and weight.
Table 2. Correlations of age and anthropometric measurements with creatinine excretion.

|       | Boys' |         |         | Girls |         |         |
|-------|-------|---------|---------|-------|---------|---------|
|       |       | n       | r       |       | n       | r       |
| Age   | 65    | 0.88*** |         | 54    | 0.90*** |         |
| Height| 65    | 0.91*** |         | 54    | 0.88*** |         |
| Weight| 65    | 0.96*** |         | 54    | 0.94*** |         |
| SFT²  | 58    | -0.31*  |         | 49    | 0.69*** |         |
| SFS²  | 58    | -0.42***|         | 49    | 0.68*** |         |
| AMA²  | 58    | 0.91*** |         | 49    | 0.70*** |         |
| FAT²  | 58    | 0.07    |         | 49    | 0.71*** |         |
| FFM²  | 58    | 0.96*** |         | 49    | 0.92*** |         |

Table 3. Regression equations relating 24-h urinary creatinine excretion (CRD) with age and body measurements.

|       | Equation               | n   | r   | r²   |
|-------|------------------------|-----|-----|------|
| Boys  | CRD = -356 + 116.1(age) | 65  | 0.880 | 0.774 |
|       | CRD = 61 + 26.4(age) + 4.14(age)^2 | 65  | 0.895 | 0.801 |
|       | CRD = -2,039 + 21.16(Ht) | 65  | 0.910 | 0.828 |
|       | CRD = 1,369 - 29.74(Ht) + 0.1845(Ht)^2 | 65  | 0.937 | 0.877 |
|       | CRD = -304 + 33.67(Wt)  | 65  | 0.965 | 0.931 |
|       | CRD = -221 - 0.94(Ht) + 35.01(Wt) | 65  | 0.965 | 0.931 |
|       | CRD = 564 - 7.15(Ht) + 39.76(Wt) | 58  | 0.965 | 0.931 |
| SF², AMA² | -16.5(SF) + 0.0616(AMA) |      |      |      |

|       | Equation               | n   | r   | r²   |
|-------|------------------------|-----|-----|------|
| Girls | CRD = -129 + 77.6(age) | 54  | 0.901 | 0.812 |
|       | CRD = -1,337 + 15.26(Ht) | 54  | 0.882 | 0.778 |
|       | CRD = -126 - 25.00(Ht) + 0.1581(Ht)^2 | 54  | 0.915 | 0.837 |
|       | CRD = -80 + 23.08(Wt)  | 54  | 0.942 | 0.887 |
|       | CRD = -330 + 2.74(Ht) + 19.57(Wt) | 54  | 0.944 | 0.891 |
|       | CRD = -502 + 4.36(Ht) + 20.98(Wt) | 49  | 0.919 | 0.844 |
| SF², AMA² | -1.0(SF) - 0.0387(AMA) |      |      |      |

*Sum of skinfolds (SFT+SFS).  bArm muscle area.
Creatinine excretion is plotted against age, height, and weight in Fig. 3. The 24-h creatinine excretion increases linearly or curvilinearly according to the increase in age, height, and weight. Correlations between age, height, weight, AMA, and FFM and creatinine excretion were highly significant (Table 2).

Creatinine excretion was estimated using the variables shown in Table 3. For Eqs. 1 to 3, age, height, and weight were each entered into the equation, and the second power of the same variable was also added only when it improved the regression estimate to a significant degree. Among the first three equations, weight showed the highest linear relationship with creatinine excretion. Following the entry of weight, height was entered in Eq. 4, which resulted in no further improvement of regression. In the multiple regression Eq. 5, height, weight, the sum of skinfolds (SFT + SFS), and AMA were used to estimate the creatinine excretion of children aged 7 years and older. Correlations ($r^2 = 0.931$ for boys, $r^2 = 0.844$ for girls) were not improved in comparison to Eqs. 3 and 4. Stepwise regression analysis was also attempted using the following six variables: height, height$^2$, weight, AMA, weight/height, and weight/height$^2$. Following the first entry of weight into the regression, none of the other five variables further improved the estimation (results not shown).

**DISCUSSION**

Twenty-four hour urinary creatinine excretion is known to increase as body size increases during growth in Caucasian children (8, 9). In the present study, Japanese children also showed an increase in 24-h creatinine excretion during growth (from ages 2 to 18 years). Urinary creatinine excretion was further related to several sets of predictor variables (Table 3), and more than 88% of the variation in 24-h creatinine excretion was explained by either of the following two sets of variables: weight in Eq. 3, and height and weight in Eq. 4. Thus, in a given sample of Japanese children, 24-h urinary creatinine excretion can be estimated based on weight alone, or on weight and height.

The predicted creatinine excretion values in the present study were higher in comparison to those obtained by the Graystone's equation (8) (Fig. 4). The difference between the diet in the present study (normal diet) and that in Graystone’s study (low-creatinine diet) may explain the difference. According to Bleiler and Schedl (10), ingestion of creatine- and creatinine-free diets with adequate protein, lowers creatinine excretion by as much as 30%. Thus, when the actual muscle mass is predicted by multiplying the 24-h creatinine excretion by a certain factor (appraisal of muscle mass (kg) equivalent to 1 g of urinary creatinine excretion), the result obtained is influenced by the amount of dietary intake of creatine and creatinine. For example, Graystone (8) used 20 as the factor. However, in the present study, a much lower value is recommended. Because estimated excretion in the present study was 10–30% higher than Graystone’s estimation (Fig. 4), the factor should be 10–30% lower (e.g., 14–18) than 20. In order to confirm this,
Table 4. Correlations of anthropometric measurements with creatinine excretion. Comparison of present study with Trowbridge's study.

|                | Present study<sup>a</sup> | Trowbridge's<sup>b</sup>   |
|----------------|---------------------------|----------------------------|
|                | Boys  | Girls | Sexes combined | Boys  | Girls | Sexes combined |
|                | (n=14)| (n=9) | (n=14)         | (n=14)| (n=9) | (n=14)         |
| Height         | 0.60  | 0.57  | 0.71           |       |       |                |
| Weight         | 0.52  | 0.78  | 0.69           |       |       |                |
| AMA<sup>c</sup>| 0.44  | 0.70  | 0.86           |       |       |                |
| SFT<sup>d</sup>|       |       | -0.45          |       |       |                |
| SFS<sup>e</sup>|       |       | -0.25          |       |       |                |
| SF<sup>f</sup>| 0.04  | 0.53  |                |       |       |                |

<sup>a</sup>Only data on children aged 9 to 10 years are shown.  
<sup>b</sup>Children aged 2 to 6 years.  
<sup>c</sup>Arm muscle area.  
<sup>d</sup>Triceps skinfold thickness.  
<sup>e</sup>Subscapular skinfold thickness.  
<sup>f</sup>Sum of skinfolds (SFT+SFS).  

more data on Japanese children must be collected under different dietary settings.

Upper arm circumference has been advocated for assessing nutritional status. Trowbridge et al. (11) demonstrated that AMA was a powerful predictor of creatinine in children aged 2 to 6 years. However, in the present study, height and weight showed a higher correlation with creatinine excretion than did AMA. In

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Table 4, only data on children aged 9–10 years are shown with calculated correlations. Even in this limited age group, height or weight showed a higher correlation with excretion. Thus, in a given sample, AMA is not a better predictor of creatinine excretion than weight and height.

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