Total Body Potassium in Normal Children

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Extract

Normative data for total body potassium on 462 children (232 boys and 230 girls) are presented. The regression of total body potassium on weight can be described as a straight line for males (grams K = $4.32 + 2.12 \times \text{weight}$) and two significantly different lines for females (grams K = $-1.50 + 2.32 \times \text{weight}$ for weight ≤ 30 kg, and grams K = $34.90 + 1.11 \times \text{weight}$ for weight > 30 kg), with less potassium per kilogram for females weighing more than 30 kg. No sex-related difference is found between 12 and 30 kg. When the regression of total body potassium on height is examined, it is found that a logarithmic transformation of potassium values results in a similar pattern, with no sex-related differences between 100 and 135 cm and less potassium per centimeter in females over this height. For males, log K in grams = $1.761 + 0.0182 \times \text{cm of height}$; and for females, log K in grams = $1.595 + 0.01942 \times \text{cm for height} \leq 135$ cm, and log K in grams = $2.574 + 0.01215 \times \text{cm for height} > 135$ cm. The logarithmic transformation of K *versus* height is proposed as a standard because it reflects changes in slope associated with known physiologic and endocrinologic changes occurring with puberty and may be more sensitive than weight in predicting abnormal values in individual patients.

Speculation

Since the regression of total body potassium on height appears to be a straight line common to both sexes 100-130 cm tall, with a diverging line indicating progressively less potassium per centimeter for females over 135 cm in height, these data were compared with available data for infants. The total body K values of infants between 50 and 80 cm in length appear to fall on a line with a steeper slope than values of children 100 to 135 cm tall. This observation suggests that, during the 1st year of life, increasing total body potassium per centimeter of length reflects maturation of body composition. Further extension of such observations to low birth weight infants might be expected to give information on their body composition.

Introduction

Interpretation of the clinical significance of total body potassium determinations depends upon normative data and their relations to other measures of body size. Presentation of normative data should be in a form that will reflect the physiologic changes of normal

growth and be sensitive to pathologic changes. A semi-logarithmic regression on height appears to meet these criteria for total body potassium.

Subjects were 232 boys and 230 girls, ages 3-18 years. They were from a middle socioeconomic background, in apparent good health, and were free of known acute or chronic disease. They lived in or near Columbia,

Missouri. More than 70% of the children fell within the 16th and 84th percentiles of the Iowa Growth Charts [10] and were evenly distributed within the tolerance intervals for all ages. No obese children were included.

Methods

Total body potassium was calculated from whole body counting of γ emissions of naturally occurring ^{40}K , using the University of Missouri's 2π liquid scintillation counter [5]. Calibration curves for ^{40}K were determined by counting a known amount of KCl in water in plastic phantoms and ascertaining the efficiency of various sizes and shapes.

Daily counts of three female and three male adults for 10 days and of two adults over a period of 4 years have shown a coefficient of variation of 2.5%.

The children, dressed in hospital gowns, lay prone on a hospital cart centered under the counter, which was lowered to 1 inch from their buttocks. Three 5-min counts were taken and the average of before and

after 5-min background counts was subtracted. The net counts per minute were corrected for an efficiency factor based upon body weight derived from the calibration curve previously mentioned. Standing height was measured to the nearest centimeter against a calibrated wall, using a headboard for horizontal fit. Weight was measured on a laboratory scale to the nearest 100-g interval.

Statistical Methods

The line segments were investigated using standard analysis of covariance techniques, as in Scheffé [16]; that is, several line segments were fit, using least squares estimates, and the differences in slopes were analyzed by the F test. The models using two line segments were fit by using a search technique of considering many possible break points, fitting the lines independently, and comparing the residual sums of squares. The tolerance intervals were constructed using a technique described by Miller [12]. The tolerance intervals for the two line models were constructed using the Bonferroni inequality. The weights for the weighted least squares models were determined empirically. A standard deviation approximately proportional to the mean was found, and standard weighted least squares procedures (as in Scheffé) were used.

Results

When the values for total body K for 232 boys were plotted against their height, a curvilinear relation was found (Fig. 1). The tolerance region for the central 68% of the population (16th and 84th percentiles) is shown. Several transformations of the data were investigated, and, for height and total K, it was found that $\log K$ gave a straight line relation with height (Fig. 2). The linearity was confirmed by considering consecutive height categories every 10 cm from 90 to 190 cm and investigating least square lines of fit for each category. No statistically significant differences in slope were found ($P > 0.20$). The lines represent least square lines of fit for the available data.

Figure 3 depicts the untransformed K/height relation of data for 230 girls, showing a curvilinear relation. Plotted on a semilog scale, these data show a statistically significant difference in slope between heights less than and greater than 135 cm (Fig. 4). The slope of the line for females less than 135 cm tall is not statistically significantly different from the slope of the male data ($P > 0.10$) (Fig. 5). However, the slope of the line for data for females greater than 135 cm is

Fig. 1. Regression line for the mean and the tolerance region for 68% of the population for total body K versus height for 232 boys.

Fig. 2. Regression line for the mean and the tolerance region for 68% of the population for the log of total body K versus height for 232 boys.

Fig. 4. Regression line for the mean and the tolerance region for 68% of the population for the log of total body K versus height for 230 girls.

Fig. 3. Regression line for the mean and tolerance region for 68% of the population for total body K versus height for 230 girls.

Fig. 5. Regression line for the mean and the tolerance region for 68% of the population for the log of total body K versus height for 432 children age 3-18 years.

Fig. 6. Regression line for the mean and the tolerance region for 68% of the population for total body K versus weight for 432 children age 3-18 years.

Table I. Regression equations for total body K on weight or height

		SE		SD
		Inter- cept	Slope	
Weight				
Females				
K, g = -1.50 + 2.32 × wt,	2.02	0.10	0.24	
for weight ≤ 30 kg				× wt
K, g = 34.90 + 1.11 × wt, for	4.66	0.10	0.20	
weight > 30 kg				× wt
Males				
K, g = 4.32 + 2.12 × wt	1.12	0.04	0.26	
				× wt
Height				
Females				
log K, g = 1.595 + 0.01942 ×	0.20	0.0017	0.10	
cm for height ≤ 135 cm				
log K, g = 2.574 + 0.01215 ×	0.20	0.0013	0.09	
cm for height > 135 cm				
Males				
log K, g = 1.761 + 0.0182 × cm	0.05	0.0003	0.11	

statistically significantly different from the slope of the male data ($P < 0.01$).

In Figure 6, untransformed data for total body K compared with weight are shown. An empirical investigation of transformation of data did not reveal any

improvement in the fit of the model. There is no sex-related difference below 30 kg. For weights greater than 30 kg, a significant change in slope occurs for females ($P < 0.01$), but not for males. The K/weight data are shown in order to dramatize the wider spread of data when the factor of fat is included.

Total body K compared with surface area does not add anything to our observations.

Table I gives the regression equations which describe the relation of total body K to height and weight.

Discussion

There are differences of opinion as to the best assessment of total body potassium. Surveyor and Hughes [17] have presented data that support the view that greater reliance should be placed on measurements of whole body ^{40}K rather than exchangeable ^{42}K . Cohn and Dombrowski [6], as well as Tyson *et al.* [18], have used ^{42}K for *in vivo* calibration of their whole body counters with humans, recognizing the problems of geometry and counter variability. We have used ^{42}K in animal studies but not in the studies with children.

Like other investigators who use large scintillation tanks for whole body counting techniques, we are not

able to ascertain the exact distribution of K along the length of the body. We prefer the K/height relation in our analyses because fat, which is "K-poor," can be bypassed in the comparisons of male and female subjects. The efficiency correction factor for our counter is based on body weight, and, because no obese children were measured for this study, the effect of adiposity in lowering counter efficiency is not a variable.

If sensitivity in detecting abnormal values is an important criterion in presenting normative data, there are several recent studies indicating that height is of greatest value in detecting deviations from normal. Cheek, Mellits, and Elliott [3] have shown that height as well as weight is essential to the construction of multivariable equations for predicting lean body mass and body water in the normal child. In a more recent paper, Cheek *et al.* [4] used body length for the detection of excess growth of lean and adipose tissue. Their concurrent observation that ^{40}K counting was less reliable than body water in predicting lean body mass in the obese patient is a valid criticism of the technique of whole body counting. However, this criticism does not alter the validity of the fact that body length is an essential parameter in interpreting abnormal body composition. In the type of undernutrition found in chronic renal disease, we have observed several patients in whom ^{40}K counting gave normal values for weight but abnormally low values when based on length [7].

In the final analysis of our data, we have found that using a logarithmic transformation of total body K for comparison with height gives a straight line relation which is similar to the total body K/weight relation. The K/weight lines are not restricted to go through the origin. In fact, we speculate that there may be a change in slope for infant growth.

Comparison of our data with those of Cheek [2] shows no differences for the males for weight or height whether expressed arithmetically or as a logarithmic transformation. For the females, however, although Cheek's data are similar to ours, the larger sample in our study gives an improved fit using a two-line model for total body potassium and weight. The arithmetic regression of total body K on height for females, which Cheek presents as a straight line, is significantly different in slope from both of ours ($P < 0.01$). In the logarithmic transformation of K/height data, the use of two lines in the regression equations has the advantage of permitting the same regression line to be used for both sexes before the onset of puberty.

Comparison of our data with those of 2420 boys and

1900 girls aged 6–21 years, measured in a 2π liquid scintillation whole body counter by Oberhausen *et al.* [14] in Germany, is not strictly possible from their published report because they have reported only age-specific median values for height, weight, and K. These age-specific median values, however, fall within the tolerance regions of our data as presented here. Age-specific data of Allen *et al.* for total body K and weight of 341 boys and 284 girls [1] "counted" at the Los Alamos 4π liquid scintillation counter, when plotted on our scale, are very close to our mean values. These investigators have not reported height values. We have measured several adults at both our counter and at Los Alamos' and have obtained almost identical counts for total body K.

Individual data of Cohn and Dombrowski [6] on two males and five females who are the same age range as ours also fall within the tolerance regions of our study.

Between 12 and 30 kg of weight and 100 and 135 cm of height, our data show no sex-related differences in total body K. Above these values, girls have less K per centimeter of height and per kilogram of weight than do boys. This pattern suggests that sex-related differences emerge at about 10 years of age, just below the median age for the beginning of acceleration in growth on the Iowa Growth Charts [10]. This probably has physiologic and endocrine significance. Although various investigators have found sex-related differences starting at infancy [15], we have not found them either by ^{40}K studies [9] or by body water compartments [8] in preschool children.

Projection of the regression line for children of both sexes toward early infancy is limited by the small amount of data available which include height measurement. When the data of observations by Maresh and Groome [11] on five infants and the means of 64 1-month infants studied by Novak *et al.* [13] are plotted on the same scale as our data for older children, it seems probable that there is a change in slope in the regression line for K/height for infants between 50 and 80 cm in length which is particularly dramatic in the logarithmic transformation (Fig. 7). Since this component coincides in age with the maturation of body composition suggested by Wallace [19], we are speculating that this change in slope, if confirmed by further studies, will also have a physiologic significance. As more sensitive equipment becomes available, total body potassium estimations might contribute to understanding some of the body composition changes in the low birth weight infant.

Fig. 7. Infant data of Maresh and Groome [11] and Novak *et al.* [13] plotted as log K versus height and compared with data of this study.

Summary

Total body K plotted against height shows a curvilinear relation for both boys and girls aged 3–18 years. When these K data are plotted on a semilog scale, the relation can be expressed graphically by a single regression line for the boys' data, but for girls it is better expressed by two lines with a change in inclination at 135 cm of height. No sex-related differences occur for total body K of the children between 100 and 135 cm.

Total body K plotted against weight is best described by a single regression line for boys and two lines for girls. No sex-related differences occur between 12 and 30 kg.

References and Notes

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