Total body potassium and body fat estimation in relationship to height, sex, age, malnutrition and obesity

C. J. EDMONDS, B. M. JASANI AND T. SMITH
MRC Department of Clinical Research, University College Hospital Medical School, London

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Summary

1. Total body potassium was estimated by $^{40}$K measurement with a high-sensitivity whole-body counter in normal individuals over a wide age range and in patients who were obese or were grossly wasted as a result of various conditions which restricted food intake.

2. Potassium concentration (mmol/kg body weight) fell with increasing age over 30 years in both normal males and females, but when individuals of different age groups were matched for height, a significant fall in total body potassium with increasing age was observed only in males. Total body potassium of females was about 75% that of males of similar height when young, the sex difference decreasing with ageing. In the normal population, total body potassium was significantly correlated with height and with weight; regression equations for various relationships are given.

3. Fat-free mass was estimated from total body potassium, values of 65 and 56 mmol of potassium/kg fat-free mass being used for males and females respectively. Body fat estimated by this method correlated well with skinfold measurements over a wide range of body weight but in malnourished individuals having inadequate food intake there was considerable discrepancy and present formulae for estimating fat-free mass from total body potassium appear unsatisfactory in malnutrition. Considerable differences between expected and observed values of total body potassium were found in muscular individuals and in normal individuals who were thin but whose body weight was relatively constant.

4. The patients with malnutrition were low both in body fat as estimated by skinfold thickness and in total body potassium estimated on the basis of height. Plasma potassium was, however, normal and potassium supplements did not increase the total body potassium.

5. Total body potassium of obese individuals was not significantly different from that of normal weight individuals on the basis of height. Total body potassium fell on weight reduction with a very low energy diet of 1260 kJ (300 kcal.) daily but changed little with a 3300 kJ (800 kcal.) diet over several months' observation.

6. For overweight, obese individuals, total body potassium was best predicted from the individual's height. For those whose body weight was less than expected, the use of weight gave the best prediction but the error was considerable when the weight deviation was large.

Key words: anthropometry, emaciation, fat-free mass, obesity, thinness, total body potassium.

Introduction

Potassium is the principal intracellular cation and its concentration in lean tissue appears to be relatively constant over a wide age range (Widdowson, McCance & Spray, 1951). Thus measurement of body potassium offers a means of determining the mass of the lean tissue and so of fat in the body.
The introduction of highly sensitive whole-body counters has made feasible measurements of total body potassium in patients without the necessity of giving radioactive substances. These counters measure the body’s content of potassium-40, the naturally occurring radionuclide of potassium, which emits $\gamma$ rays of energy 1.46 MeV. In Nature, potassium-40 forms a constant proportion (0.0118%) of stable potassium and so, from the potassium-40 content, it is possible to calculate the amount of potassium present.

In the present report, we describe the results of using the method to study changes of total body potassium occurring in ageing, in malnutrition associated with various clinical conditions, in obesity and during the dietary treatment of obesity. Usually, in studies of alterations in total body potassium, body weight has served as reference index so that changes are expressed in amounts of potassium per kg body weight. There are, however, obvious limitations of this method since, in many pathological states, body weight is itself altered. It is particularly unsatisfactory in a study of patients who are obese or who are in malnutrition.

Body height would seem to offer a more suitable index as height is easy to measure and changes little over many years of adult life. It has been widely used as the basis for weight prediction but has only once been employed as a reference index for total body potassium as estimated by measurement of potassium-40 (Boddy, King, Hume & Weyers, 1972). This recent study of normal individuals showed very good correlation of total body potassium with height and an appreciably smaller standard deviation from the regression than when the correlation was with body weight.

The object of the present work was to re-examine the relationship of total body potassium to height in normal individuals and then to apply the results to a study of the changes of total body potassium in obese and wasted patients. We have also made measurements of skinfold thickness as these offer a relatively simple means of estimating body fat (Keys & Brozek, 1953; Parizkova, 1961; Seltzer, Goldman & Mayer, 1965; Durnin & Rahman, 1967) and may also prove a useful anthropometric measurement suitable for clinical practice in predicting an individual’s expected total body potassium (Kjellberg & Reizenstein, 1970; Burkinshaw, Cotes, Jones & Knibbs, 1971).

Methods

Individuals studied

The normal volunteers (136 males, seventy-four females) were students, nurses, medical and scientific staff and their relatives. All were in good health, free from any condition known to disturb potassium metabolism and their body weight did not deviate by more than 15% from that expected for their height, age and sex.

The patients referred to subsequently as malnourished (three males aged 20–40 years and nine females aged 18–42 years) were all hospital inpatients; they had an observed inadequate food intake and had been losing weight during preceding months. Seven of these patients had established anorexia nervosa; one had a malignant stricture and two benign strictures of the oesophagus; one had scleroderma involving the oesophagus and one patient had prolonged anorexia associated with a gastric ulcer. None of the patients had been treated with drugs known to affect potassium metabolism.

Forty obese patients (eleven males aged 15–55 years, twenty-nine females aged 16–56 years) were studied. Their body weights were at least 20% above that expected for their height, age and sex, and only patients in whom the diagnosis of simple obesity had been established were studied. Diuretics and other drugs known to influence potassium metabolism were not given during the study or during the 4 weeks preceding it. Twelve of the obese patients were admitted to hospital and received a diet providing 1260 kJ (300 kcal.) daily. The estimated composition of the diet was: protein 20 g, carbohydrate 35 g, sodium 40 mmol, potassium 45 mmol. Five patients were subsequently treated as outpatients on a diet providing 3300–5000 kJ (800–1200 kcal.) daily.

Anthropometric measurements

Height was measured with the subject standing in socks. Body weight was measured with outer clothing removed, 0.3 kg being deducted to allow for clothing worn. Skinfold thicknesses were measured at four sites: over the mid-points of the biceps and triceps muscles, below the inferior angle of the scapula and above the supra-iliac crest (Durnin & Rahman, 1967). The skin fold was gently lifted from the underlying tissues and specially designed calipers were used (Edwards, Hammond, Healy, Tanner &
Total body potassium

Whitehouse, 1955). The arithmetic average of the four readings was taken as skinfold thickness.

Measurement of total body potassium

The potassium-40 content of each individual was measured with a highly sensitive liquid-scintillation whole-body counter (Barnaby & Jasani, 1968; Jasani & Edmonds, 1971). Individuals removed outer clothing, shoes and watches before entering the counter and an 800 s count was made. A potassium standard source (3 kg of potassium chloride in a polythene container) was counted for radioactivity before and after each measurement and a number of 800 s background measurements were also recorded with the counter containing a water-filled phantom. Complete details of the methods used for calibration and assessment of the errors involved have been previously described (Barnaby & Jasani, 1968). Together these errors meant that the coefficient of variation for measurement of an individual having a total body potassium of 3500 mmol was 4.2%. The counter was calibrated with phantoms containing a solution of potassium chloride in distilled water, and by giving a small dose of potassium-42 (about 1 μCi) to some normal, obese and wasted individuals (Barnaby & Jasani, 1968). The expressions \( K_{BW} \) and \( K_{FFM} \) used subsequently refer to the total body potassium divided by the body weight or by the fat-free mass respectively.

Estimation of fat-free mass and fat

The fat-free mass was calculated from an empirical relationship

\[ \frac{\text{Total body } K}{K_{FFM}} \]

the measured value of total body potassium being used and assuming 65 mmol/kg and 56 mmol/kg as \( K_{FFM} \) for males and females respectively. These values were derived from measurements made by us on ten males and ten females of normal weight and aged 18–46 years. Body potassium was determined for each individual and the fat-free mass estimated from height and weight by using the formulae of Hume & Weyers (1971) and Pace & Rathbun (1945). The value of \( K_{FFM} \) for each sex in this age range could then be calculated. The values obtained were similar to those found by Womersley, Boddy, King & Durnin (1972) and for males are consistent with results of cadaver studies (Widdowson et al., 1951; Forbes et al., 1961). Data from female cadaver analyses are inadequate for satisfactory comparison. Body fat was determined by subtracting the calculated fat-free mass from the total body weight.

For each individual, an expected body weight based on sex, height and age, was obtained from Society of Actuaries Tables (1959).

Computer analysis was employed to test the linear regressions of total body potassium on height, on weight and on height and weight combined. Standard deviations from the regressions are expressed as percentages of the mean values for total body potassium in the three groups of normal subjects. Student's t-test was used to test the significance of the difference in values between normal males and females matched for height (Table 1). The expected total body potassium for a given individual was determined with the derived regression equation relating body potassium and height of normal individuals in the appropriate age and sex groups. Expected \( K_{BW} \) was calculated from the expected total body potassium and the expected weight for each individual. The results are given as mean values ± SEM unless otherwise stated.

<table>
<thead>
<tr>
<th>Age range (years)</th>
<th>n</th>
<th>Height (cm)</th>
<th>Female</th>
<th>Male</th>
<th>Significance of total body K difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Body wt. (kg)</td>
<td>Total body K (mmol)</td>
<td>Body wt. (kg)</td>
</tr>
<tr>
<td>16–19</td>
<td>6</td>
<td>169 (161–175)</td>
<td>59.9 (54.2–73.7)</td>
<td>2550 ± 118</td>
<td>65.8 (49.1–71.9)</td>
</tr>
<tr>
<td>50–69</td>
<td>7</td>
<td>161 (154–169)</td>
<td>71.7 (65.9–80.5)</td>
<td>2230 ± 125</td>
<td>68.7 (58.5–74.1)</td>
</tr>
</tbody>
</table>

Table 1. Comparison of total body potassium of normal males and females matched for height in each sex group

Results are expressed as mean values ± SEM or range.


Results

Effect of age, sex and height

Only those values derived from the normal individuals whose weights were within ±15% of their expected weights were used in this part of the present investigation. When total body potassium was expressed in relation to body weight \( K_{bw} \), it was found to have maximum value in the age group 20–29 years and fell with increasing age in both sexes. In all age groups, the values were lower in females than in males. For example, in the females, \( K_{bw} \) was 41.1 ± 1.00 mmol/kg \((n = 17)\) in the age group 20–29 years and 33.0 ± 1.67 mmol/kg \((n = 10)\) in the age group 60–69 years. For males, the corresponding values were 52.5 ± 1.21 \((n = 41)\) and 44.7 ± 1.49 \((n = 15)\) mmol/kg respectively.

The changes in potassium concentration \( K_{bw} \) are, however, determined not simply by changes in total body potassium but also by changes of body weight, which itself usually alters considerably with ageing. Height alters much less and so to examine the influence of age on total body potassium it appears reasonable to study groups of individuals matched for height. Accordingly the results on the normal males and females were divided into eight groups by age (16–19, 20–29, 30–59, 60–69) and sex, and from these age groups, sets of individuals matched for height could be selected (Fig. 1). Results could only be used from fifty-six of our normal individuals owing to the restrictions of matching. Seven individuals from each age group matched for height in the male and female series were used. The average height of the males was 175 \((\text{range} 165–183)\) cm and of the females 161 \((\text{range} 156–167)\) cm. In males, total body potassium was maximum in the age group 20–29 years and subsequently tended to fall with increasing age so that the value for the age group 60–69 years was about 13% less than that for the age group 20–29 years. With the females, however, a statistically significant change with age could not be demonstrated although total body potassium was lowest in the oldest group.

Though the results shown in Fig. 1 suggested a considerable sex difference in total body potassium, a direct comparison between the sexes was not possible within these groups because of the difference in height. It was necessary therefore to select from our normal population groups, males and females who were matched for height and age group and, when this was done, there was an obvious sex difference (Table 1). The females had a markedly lower total body potassium than males of similar age and height in both age groups. The difference was, however, greater in the younger group where the females had an average total body potassium of 73% that of the males of similar stature whereas in the older group the proportion was 88%.

To obtain the best relation between total body potassium and body height it is therefore necessary to take into account both age and sex. From the results on the normal individuals, the relationship between total body potassium and height, total body potassium and body weight and total body potassium and height and weight together were examined. In the males, the age groups 20–29 years and 30–59 years contained most individuals and were treated separately. In the females, a fairly large group was obtained by combining the age groups 20–29 years and 30–59 years, which could be justified as total body potassium did not appear to change with age over this range. The correlation was significant \((P < 0.01)\) in all cases (Table 2). The relationship between total body potassium and height established in this normal group was used as a basis for the investigation of malnourished and obese patients described subsequently.

![Fig. 1. Changes in total body potassium with age (mean ± 1 sdm). Males (●) and females (○) were grouped by age, 16–19, 20–29, 30–59 and 60–69 years, with seven individuals in each group. The groups were matched for height in each sex, the average male height being 175 (range 165–183) cm and average female height 161 (range 156–167) cm. The difference between the male groups 20–29 years and 60–69 years was significant \((P = 0.025)\).](image-url)
Total body potassium

TABLE 2. Relation between total body potassium, height and weight in normal subjects

<table>
<thead>
<tr>
<th>Total body K (mmol) related to</th>
<th>Sex</th>
<th>Age range (years)</th>
<th>n</th>
<th>Regression equation</th>
<th>Correlation coefficient</th>
<th>so from regression (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>M</td>
<td>20–29</td>
<td>43</td>
<td>$42.8H - 3871$</td>
<td>0.64</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>30–59</td>
<td>53</td>
<td>$44.4H - 4434$</td>
<td>0.74</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>20–59</td>
<td>44</td>
<td>$22.0H - 1267$</td>
<td>0.46</td>
<td>13.4</td>
</tr>
<tr>
<td>Weight</td>
<td>M</td>
<td>20–29</td>
<td>43</td>
<td>$42.4W + 664$</td>
<td>0.70</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>30–59</td>
<td>53</td>
<td>$32.9W + 840$</td>
<td>0.68</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>20–59</td>
<td>44</td>
<td>$18.5W + 171$</td>
<td>0.55</td>
<td>12.5</td>
</tr>
<tr>
<td>Height and weight</td>
<td>M</td>
<td>20–29</td>
<td>43</td>
<td>$21.6H + 29.6W - 2226$</td>
<td>0.74</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>30–59</td>
<td>53</td>
<td>$31.0H + 16.8W - 3337$</td>
<td>0.78</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>20–59</td>
<td>44</td>
<td>$9.5H + 14.5W - 112$</td>
<td>0.57</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Malnutrition

All these patients had malnutrition due to inadequate food intake. Their body weights were from 19 to 41% below their expected weights. The great reduction in subcutaneous fat was shown by skinfold measurements, which did not exceed an average value of 5.6 mm in any patient (Fig. 2). The observed values for total body potassium were 14–46% lower than expected but potassium concentration ($K_{aw}$) was not significantly altered with wasting (Table 3). Plasma potassium in all these patients was consistently within the normal range ($4.1 \pm 0.1 \text{ mmol/l}$) compared with $4.2 \pm 0.3 \text{ mmol/l}$ observed in a control group measured during the same period. Potassium supplements, as potassium chloride (Slow-K, Ciba) up to six tablets (48 mmol of potassium) daily for 2 weeks did not affect the total body potassium. Calculation of the proportion of body fat from the measurement of total body potassium gave what appeared to be an erroneous result, all the individuals seeming to have a high proportion of fat. This estimation was inconsistent with the skinfold measurements (Fig. 2) and with the appearance of the patients.

One of our patients increased her weight considerably during the study. She had an oesophageal carcinoma and was initially considerably wasted. After surgical treatment, body weight rose from

![Fig. 2. Relation between skinfold thickness (average from four sites) and fat content expressed as percentage of body weight, and calculated from the observed total body potassium. The results were from forty-three normal individuals (○: fifteen female and twenty-eight male) aged 18–56 years and from all the malnourished (△) and obese (●) patients. The regression line was calculated from the normal and obese individuals only: $0.5x + 1.59$, $r = 0.86$, $P < 0.001$.](image)
**Table 3. Total body potassium in underweight, but otherwise normal, individuals and in patients with wasting or obesity**

Results are expressed as mean values±SEM or range. M, male; F, female.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>n</th>
<th>Body wt. (kg)</th>
<th>Total body K observed</th>
<th>Kbw observed</th>
<th>Skinfold thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Observed</td>
<td>Expected</td>
<td>Expected(1)</td>
<td>Expected(2)</td>
</tr>
<tr>
<td>Underweight, normal</td>
<td>4</td>
<td>49.7±5.4</td>
<td>61.4</td>
<td>80.9±5.4</td>
<td>99.8±6.0</td>
</tr>
<tr>
<td></td>
<td>(M2 F2)</td>
<td>(40–56)</td>
<td>(48–69)</td>
<td>(55–93)</td>
<td>(5–9–3)</td>
</tr>
<tr>
<td>Wasted</td>
<td>12</td>
<td>42.1±5.1</td>
<td>62.2</td>
<td>66.3±3.1</td>
<td>96.5±4.1</td>
</tr>
<tr>
<td></td>
<td>(M3 F9)</td>
<td>(24–58)</td>
<td>(40–76)</td>
<td>(3–6–9)</td>
<td>(3–6–5–6)</td>
</tr>
<tr>
<td>Obese</td>
<td>40</td>
<td>92.0±5.0</td>
<td>59.8</td>
<td>102.6±3.1</td>
<td>68.7±3.0</td>
</tr>
<tr>
<td></td>
<td>(M11 F29)</td>
<td>(68–121)</td>
<td>(41–78)</td>
<td>(15–2–33)</td>
<td>(15–2–33)</td>
</tr>
</tbody>
</table>

(1) Expected total body K based on values related to height, sex and age obtained from the normal population.
(2) Expected Kbw was calculated from the expected total body K and the expected weight for each individual.

35 kg to 43 kg at 6 weeks post-operatively and to 52 kg at 4 months, her expected body weight being 59 kg. These changes were accompanied by a rise of total body potassium from 1330 mmol initially to 1550 mmol at 6 weeks post-operatively and 1890 mmol at 4 months. Her expected total body potassium was 2300 mmol. Both body weight and body potassium did therefore increase substantially with refeeding but the rise of weight was relatively greater so that Kbw fell slightly.

**Obesity**

Skinfold measurements were greater in the obese patients than in most of the normal individuals and in the majority the average value exceeded 20 mm (Fig. 2). The proportion of body fat calculated from potassium-40 determination was 35% or more of body weight and in two it exceeded 70%. Comparison of the values for total body potassium measured in the obese patients with those expected from the patients' height, age and sex (Table 3) showed that, despite the great increase in body weight, the values were not significantly different from what was expected. Thus the excess of fat mass was not associated with any significant excess of fat-free mass.

In all of the patients who were treated by a very low energy diet in hospital, a similar pattern of weight loss was observed. About 40% of the weight loss observed in hospital took place during the first 10 days on the diet but no significant change of total body potassium was observed during this period. Over the whole 6 weeks, however, a significant fall of total body potassium was demonstrable, averaging about 14 mmol of potassium/kg of weight loss (Table 4) but plasma potassium concentration did not change significantly. In the subsequent out-patient follow-up period when the daily diet provided 3300–5000 kJ (800–1000 kcal.) daily, the rate of weight loss was less, averaging about 0.5 kg/week, but over the period of study a considerable fall in weight occurred without significant change in total body potassium.

**Muscular and thin individuals**

Predictions based on height and weight derived from average individuals are especially inaccurate when body constitution differs markedly from average. In professional football players, athletes and other highly trained sportsmen, for example, total body potassium may be significantly higher than in control healthy subjects taking average exercise (Norak, Hyatt & Alexander, 1968; Boddy, Hume, King, Weyers & Rowan, 1974). Three individuals measured during our study were muscular athletic men. All were somewhat above expected weight but the striking difference was in their total body potassium values, which were 18–25% higher than expected on the basis of height (Table 5). There were also two males and two females who presented as normal but had body weights lower than our defined normal limits of ±15% of that expected. All four were working normally and claimed good health. They denied weight loss and said that they had always been thin. The mean values of the observations on these four are included in Table 3. Their body weights averaged 19% and total body potassium was 20%
Total body potassium

TABLE 4. Effect of dietary treatment on body weight and total body potassium of obese patients

Results are expressed as mean values±SEM or range.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Period of treatment (weeks)</th>
<th>Body wt. (kg)</th>
<th>Total body K (mmol)</th>
<th>Fall in body wt (kg)</th>
<th>Fall in total body K (mmol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-patient 1260 kJ (300 kcal) daily</td>
<td>12</td>
<td>93.3 (88-121)</td>
<td>2390 (1690-3250)</td>
<td>8.3±0.31</td>
<td>117±29</td>
</tr>
<tr>
<td>Out-patient 3300–5000 kJ (800–1200 kcal) daily</td>
<td>5</td>
<td>87.7 (81-93)</td>
<td>2210 (1760-2460)</td>
<td>15.2±2.3</td>
<td>32±17</td>
</tr>
</tbody>
</table>

TABLE 5. Details of three muscular males with total body potassium considerably greater than expected for their height

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (years)</th>
<th>Body wt. (kg)</th>
<th>Total body K (mmol)</th>
<th>Kbw observed (mmol/kg)</th>
<th>Fat-free mass (kg)</th>
<th>Body fat (kg)</th>
<th>Skinfold thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>68.1</td>
<td>3880 (3491)</td>
<td>57</td>
<td>9</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>78.9</td>
<td>4480 (3876)</td>
<td>57</td>
<td>6.9</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>69.8</td>
<td>3790 (3063)</td>
<td>54</td>
<td>58</td>
<td>12.3</td>
<td></td>
</tr>
</tbody>
</table>

(1) Expected TBK based on height, sex and age.

TABLE 6. Accuracy of prediction of total body potassium from anthropometric data in underweight, wasted and obese patients

<table>
<thead>
<tr>
<th>Total body K (observed/expected, %)</th>
<th>Expected value from height</th>
<th>Expected value from weight</th>
<th>Expected value from height and weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight, normal</td>
<td>80.9±5.4</td>
<td>96.3±3.9</td>
<td>91.4±5.2</td>
</tr>
<tr>
<td>Wasted</td>
<td>66.3±3.1</td>
<td>81.4±4.2</td>
<td>75.2±3.2</td>
</tr>
<tr>
<td>Obese</td>
<td>102.6±3.1</td>
<td>79.8±2.8</td>
<td>85.1±2.9</td>
</tr>
</tbody>
</table>

below that expected, and skinfold thickness was relatively low.

Discussion

Variation in total body potassium with age and sex

The tendency for total body potassium to fall after the age of 20–30 years observed in the present study is similar to that found by others (Anderson & Langham, 1959; Allen, Anderson & Langham, 1960; Meneely, Ball, Ferguson, Payne, Lorimer, Weiland, Rolf & Heyssel, 1962; Anderson, 1963; Oberhausen & Onstead, 1965; Lorimer, Sinclair-Smith, Constantinides, Weiland, Ball & Heyssel, 1965; Poretti, Waser & Zuppinger, 1967; Cohn & Dombrowski, 1970; Boddy et al., 1972), measuring random groups unmatched for height. Two sex differences were observed. First, total body potassium of young females was about 75% that of males of similar height, and secondly the fall in the value with age was greater in males, so that the difference in total body potassium between males and females decreased with ageing. The potassium contained in muscle accounts on average for nearly 90% of the total body potassium and these observed sex and age differences must be largely due to differences in muscle mass. The muscle mass of males declines considerably with age whereas that of females changes much less. The fall of body potassium concentration (Kbw) with age, which is observed in both sexes, is in males largely due to a fall of total body potassium whereas in females it seems largely to result from an increase of body weight from fat accumulation.
Total body potassium and body fat

Measurement of total body potassium using a whole-body counter is a relatively simple procedure and, since storage fat contains only about 5 mmol of potassium/kg, practically all the body potassium is elsewhere. Hence, provided that $K_{FFM}$ is known, fat-free mass and body fat can be easily estimated. The values of $K_{FFM}$ we used are, however, average values so that, for any individual, the accuracy of estimating his fat-free mass from total body potassium depends on how well the average value matches his true $K_{FFM}$. The tissues of the body differ in the amount of potassium present in unit weight of the tissue, which is very low in bone and the extracellular fluid and high in the intracellular fluid. Thus variation in the proportions of the various tissues between individuals means that $K_{FFM}$ will vary from one individual to another. The sex differences in $K_{FFM}$, for example, may be due to this factor and the decline with age of the potassium-rich muscle mass in males would also tend to alter $K_{FFM}$. Our value, based on a young to middle age group, may therefore entail some error if used for estimating body fat in an elderly population. In the patients with malnutrition, the possibility of this error was especially obvious since the use of our average values for $K_{FFM}$ suggested a relatively high percentage of body fat, which was clearly wrong. The value of $K_{FFM}$ must be considerably reduced in malnutrition, probably largely in consequence of the relatively great shrinkage in the potassium-rich muscle mass, but little change in bone, which has a low potassium content. At present, therefore, some caution is necessary in using total body potassium with the average $K_{FFM}$ values to estimate body fat content in extreme of age or when body weight deviates much from normal values. This is particularly true if body weight is reduced below its normal value. The generally good agreement between percentage body fat content derived from estimation of total body potassium and skinfold measurements did, however, suggest that the total body potassium method was a useful means of body fat estimation over a fairly wide weight range from normal to obese.

Prediction from anthropometric data

To predict the normal value of total body potassium for an individual has considerable clinical use but, to make the prediction as accurate as possible, several factors must be considered. The relationship of total body potassium to body weight has been widely used but suffers from the disadvantage that, in many diseases, body weight itself is changed. From our data and results of Boddy et al. (1972) it is clear that, if sex and age are taken into account, the relationship of total body potassium to height may be clinically very useful since height is not often altered significantly in disease. Calculation of the ratio of the observed total body potassium to that expected by using various anthropometric data (Table 6) showed that with individuals who were overweight from obesity, the use of height alone was clearly superior. With underweight individuals, however, the use of weight rather than height gave the best prediction of total body potassium, although the error was considerable when there was gross wasting. No systematic study was made of the usefulness of skinfold measurements since these were only carried out in some of our normal population. Such results as we have (Fig. 2), although indicating a general relationship between skinfold thickness and total body fat, show that there is considerable variation. This is not altogether unexpected as use of skinfold thickness to predict body fat has limitations (Durnin & Rahman, 1967), particularly in that relatively few regions are measured and that a variable, large amount of fat is not subcutaneous. It seems unlikely therefore that the addition of skinfold thickness to the other data would usually be of much assistance in increasing the accuracy of the prediction of total body potassium. However, in overweight individuals the skinfold thickness can be of value in confirming that the excess of weight is due to fat rather than to muscle.

Malnutrition and obesity

In the patients with malnutrition, the values for total body potassium were very much lower than normal. Similar reductions have been observed in kwashiorkor and marasmus (Garrow, 1965) and of exchangeable potassium in adult wasting conditions (De Deuxchaisnes, Collete, Busset & Mach, 1961). In our patients, the lowering of total body potassium was probably largely due to the wasting of lean tissues and not to potassium depletion, since giving a potassium supplement was without effect. The primary factor was presumably the
reduction of cellular constituents, particularly protein, as a result of a prolonged preceding period of negative nitrogen balance.

It has been suggested that obese individuals may differ from normal weight individuals in morphological characteristics other than simply adiposity (Seltzer & Mayer, 1964). There was not, however, any evidence for this in the measurements of total body potassium, for although in obese patients this value was on average slightly higher in both males and females than expected on the basis of height, age and sex, the differences were not significant. Thus there was no evidence that their raised body weight was accompanied by an increase of lean tissue. These observations, together with those of longitudinal studies showing the relative constancy of total body potassium in individuals measured repeatedly over several months or years (Lorimer et al., 1965; Johny, Worthley, Lawrence & O’Halloran, 1970; Boddy, King, Tothill & Stray, 1971; Edmonds & Jasani, 1972; Shukla, Ellis, Dombrowski & Cohn, 1973), suggest that in healthy individuals total body potassium is constant and not influenced by excessive food intake alone.

Starvation dieting of obese patients can produce electrolyte disturbances and even death (Garnett, Barnard, Ford, Goodbody & Woodhouse, 1969; R uncie & Thomson, 1970; Sandhofer, Dienstl, Bolzano & Schwingschakl, 1973) and a considerable fall in total body potassium may occur rapidly (Drenick, Swenseid, Blahd & Tuttle, 1963; Benoit, Martin & Watten, 1965; Kjellberg & Reizenstein, 1970). Complete starvation was not used in the treatment of our patients and the very low energy diet was given only for a period not exceeding 6 weeks. It did not produce any significant electrolyte disturbances or gross depletion of potassium. There was, however, some fall of total body potassium and since potassium intake was adequate, this probably reflected a wasting of lean tissue, possibly as a result of the low protein intake. Total body potassium was reduced to about 94% of its initial value over 6 weeks, a reduction of similar magnitude to that observed in seven obese patients described in a recent study (Runcie & Hilditch, 1974). In contrast, when a diet of greater protein and energy content was used for out-patient treatment, a substantial weight loss occurred but with little change of total body potassium. Weight loss during this period was largely due to fat loss and apparently little of the lean tissue wasted.

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References


