the female cadaver had the highest concentration of potassium in FFM, namely, 72.6 mEq/kg, compared with the other values of 66.5, 66.6 and 66.8 mEq/kg.

We believe that the men in our series B have a higher concentration of potassium in FFM because they took more regular exercise than any of our other subjects. This idea is supported by similar measurements made on three athletes of international status, who were found to have potassium concentrations of 70.3, 70.0 and 60.4 mEq of K/kg FFM respectively.

We should be interested to learn whether the male subjects used by Womersley et al. (1972) were more than usually athletic.

Table 1. Means and standard deviations of the observations

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Series A</td>
<td>Series B</td>
<td>Series A</td>
<td>Series B</td>
</tr>
<tr>
<td>No. of subjects</td>
<td>20</td>
<td>11</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>Age (years)</td>
<td>25.5 ± 2.2</td>
<td>26.0 ± 6.9</td>
<td>23.7 ± 1.9</td>
<td>18.7 ± 0.4</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>72.8 ± 8.9</td>
<td>70.1 ± 7.8</td>
<td>55.1 ± 6.4</td>
<td>60.5 ± 6.9</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>62.5 ± 6.9</td>
<td>60.3 ± 6.5</td>
<td>40.3 ± 2.8</td>
<td>43.1 ± 4.0</td>
</tr>
<tr>
<td>Total potassium (mEq)</td>
<td>3670 ± 410</td>
<td>3875 ± 520</td>
<td>2309 ± 187</td>
<td>2506 ± 225</td>
</tr>
<tr>
<td>mEq of K/kg FFM</td>
<td>58.8 ± 3.3</td>
<td>64.3 ± 3.7</td>
<td>58.2 ± 4.2</td>
<td>58.3 ± 3.1</td>
</tr>
</tbody>
</table>

References


Authors' Reply

Body potassium and fat-free mass

KEITH BODDY and PRISCILLA C. KING, Scottish Universities Research and Reactor Centre, East Kilbride, and

J. WOMERSLEY and J. V. G. A. DURNIN, Institute of Physiology, University of Glasgow
Dr Burkinshaw and Dr Cotes, evidently prompted by our report (Womersley, Boddy, King & Durnin, 1972), question the validity of a difference in the amount of potassium per unit mass of fat-free mass (FFM) between the sexes. We did not claim any originality for the difference we observed as, perhaps naively, we felt it was already well-established in the literature. Some values of K/FFM for healthy subjects are quoted in Table 1. For the purposes of comparison,

Table 1. Some literature values of K/FFM (mEq/kg) in males and females

<table>
<thead>
<tr>
<th>Reference</th>
<th>Males</th>
<th></th>
<th></th>
<th>Females</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>N</td>
<td>K/FFM</td>
<td>Age</td>
<td>N</td>
<td>K/FFM</td>
</tr>
<tr>
<td>Allen, Anderson &amp; Langham (1960)*</td>
<td>22-41</td>
<td>28</td>
<td>65.5</td>
<td>16-51</td>
<td>10</td>
<td>58.5</td>
</tr>
<tr>
<td>Von Dobeln (1962)*</td>
<td>-</td>
<td>154</td>
<td>69.9</td>
<td>-</td>
<td>73</td>
<td>59.3</td>
</tr>
<tr>
<td>Oberhauser &amp; Onstead (1965)*</td>
<td>20</td>
<td>-</td>
<td>67.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>25-60</td>
<td>-</td>
<td>61.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Boddy et al. (1972b)*</td>
<td>20-77</td>
<td>49</td>
<td>67.8</td>
<td>18-72</td>
<td>54</td>
<td>59.3</td>
</tr>
<tr>
<td>Edelman &amp; Liebman (1959)</td>
<td>18-33</td>
<td>32</td>
<td>62.0</td>
<td>18-33</td>
<td>26</td>
<td>58.2</td>
</tr>
<tr>
<td>Muldowney, Crooks &amp; Bluhm, (1957)</td>
<td>34-50</td>
<td>10</td>
<td>63.5</td>
<td>34-50</td>
<td>6</td>
<td>48.4</td>
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<tr>
<td>Ikkos, Ljunggren &amp; Luft (1965)</td>
<td>22-59</td>
<td>9</td>
<td>62.4</td>
<td>18-81</td>
<td>8</td>
<td>50.5</td>
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<tr>
<td>Moore, Olesen, McMurray, Parker, Ball &amp; Bayden (1963)</td>
<td>23-54</td>
<td>10</td>
<td>67.8</td>
<td>23-51</td>
<td>10</td>
<td>62.5</td>
</tr>
<tr>
<td>Deuxchaisnes, Collett, Busset &amp; Mach (1961)</td>
<td>71-84</td>
<td>7</td>
<td>67.2</td>
<td>60-74</td>
<td>7</td>
<td>59.9</td>
</tr>
<tr>
<td>Talso, Miller, Carballo &amp; Vasquez (1960)</td>
<td>30</td>
<td>24</td>
<td>55.5</td>
<td>29</td>
<td>24</td>
<td>50.6</td>
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<tr>
<td>Corsa, Olney, Steenberg, Ball &amp; Moore (1950)</td>
<td>23-38</td>
<td>23</td>
<td>65.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Boling, Taylor, Enteman &amp; Behnke (1962)</td>
<td>21-30</td>
<td>27</td>
<td>58.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Total body K measured by whole-body monitoring.

these data have been normalized as total potassium per kg FFM, where necessary, by assuming exchangeable potassium = 0.95 x total potassium (Talso, Miller, Carballo & Vasquez, 1960; Remenchik & Miller, 1962; Surveyor & Hughes, 1968; Boddy, Davies & King, 1973a) and FFM (kg) = total body water (l) ÷ 0.73 (Pace & Rathbun, 1945). The values of K/kg FFM are consistently higher in males than in females and in most studies where both males and females were included a significant difference (P<0.05) between the sexes could be shown directly. The mean values in our males (who were not more than usually athletic) and females respectively of 66.4 and 59.7 mEq/kg FFM (Womersley et al., 1972) seem compatible with these findings and also with those in a subgroup of similar age range (corresponding mean values of 67.8 and 59.3 mEq/kg FFM) from an earlier series comprising largely medical and nursing staff (Boddy, King, Hume & Weyers, 1972b). The recapitulated findings of Burkinshaw and Cotes are also compatible with reported data though we would consider that the mean for their Group A males was at the lower end of the range rather than the mean for Group B males being extraordinarily high. It is interesting, however, that a mean value as low as 55.6 mEq/kg FFM for older males can be derived from results also using the Leeds whole-body monitor but estimating FFM from body water (Hughes, Williams & Smith, 1967). Nevertheless, systematic differences
between whole-body monitors at Leeds and East Kilbride seem an unlikely explanation for, as pointed out by Burkinshaw and Cotes, body potassium estimates in subjects measured at both centres were in good agreement (Boddy, King, Tothill & Strong, 1971). There is evidence that mEqK/kg FFM changes with age (Oberhausen & Onstead, 1965; Garrow, Fletcher & Halliday, 1965; Moore, Olesen, McMurray, Parker, Ball & Bayden, 1963) which might account partially for the differences between our findings (Womersley et al., 1972; Boddy et al., 1972b) and those of Hughes et al. (1967) but would not explain the anomaly in relation to Burkinshaw and Cotes’ Group A males.

Comparison with cadaver analysis generally requires circumspection, first because, by definition, the cadaver is not a living person and significant changes in body composition may occur between death and analysis and, secondly, because the cause of death can itself influence body composition [as Widdowson, McCance & Spray (1951) emphasize]. In the specific case cited by Burkinshaw and Cotes of the female cadaver ['L' of the study by Widdowson et al. (1951)] the notes indicate that she was a ‘thin masculine type’ and was of lower body weight than the mean of our series (Boddy et al., 1972b; Womersley et al., 1972) and that of Burkinshaw and Cotes. She was also taller than average. In particular, she committed suicide by drowning and, though ‘not obviously wasted’, the estimated period of time of immersion in water and whether this was fresh-water or salt-water was not indicated. We are unable to assess the possible influence of these factors on the composition of the body so that, while we agree that it is interesting that this female cadaver has the highest concentration of mEqK/kg FFM, the significance of this single finding is not obvious to us and its interpretation seems equivocal.

The three results obtained by Burkinshaw and Cotes demonstrate the apparent wide range of values for mEqK/kg FFM even in a restricted ‘ultra-fit’ population. The question of the influence of vigorous regular physical exercise on mEqK/kg FFM has been studied with the cooperation of the Glasgow Rangers Football Club (K. Boddy, R. Hume, P. C. King, E. Weyers & T. Rowan, paper in preparation) and it would seem improper to anticipate the publication of these findings. However, the findings are compatible with the limited literature. From the literature, mean values can be derived ranging from about 64.2 mEqK/kg FFM in Olympic male swimmers to 70.9 mEqK/kg FFM in American footballers and baseball players. It seems noteworthy that this range of mean values includes our controls (Boddy et al., 1972b; Womersley et al., 1972), those of the younger age groups, quoted in Table 1, in whom total body potassium was measured, as well as Burkinshaw and Cotes’ Group B males.

We believe that FFM is a simple and convenient concept and useful for purposes of normalization. Nevertheless, the limitations of FFM, defined as total body weight minus fat weight, must not be overlooked. Almost 20 years ago, Siri (1956) emphasized these limitations with particular reference to the measurement techniques. It seems possible that a direct estimate of total skeletal or mineral mass, which can then be excluded from FFM, will improve the interpretation of body composition studies. This possibility can be examined by measuring body potassium and then determining simultaneously total body calcium, phosphorus and nitrogen (as well as sodium and chlorine) by in vivo activation analysis (Boddy, Holloway, Elliott, Giaros, Robertson & East, 1972a; Boddy, Holloway & Elliott, 1973b).

References

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