Recalculation of the calcium requirement of adult men

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ABSTRACT

Background: There is uncertainty about the calcium requirement with particular respect to age and sex differences and the calculation of skin calcium losses.

Objective: We calculated the calcium requirement of adult men from a homogenous set of calcium balances and a robust estimate of calcium loss through the skin.

Design: We reviewed available high-quality published calcium balances in men and retrieved 219 balances; we noted a fall in calcium absorption in individuals >60 y of age. Our analysis was confined to 157 men ≤59 y of age with intakes of ≤1100 mg Ca.

Results: The mean age of the men was 38 y (range: 17–59 y), and the mean duration of the balances was 107 d (9–480 d). We assumed skin calcium losses of 40 mg Ca/d on the basis of the calcium content of insensible water loss. There was a highly significant correlation between calcium intake and the net absorbed calcium (R² = 0.59), but inspection and physiologic considerations led us to use the logarithmic transformation of intake, which yielded the equation Ca absorbed = 210 log Ca intake − 1135 mg Ca. The calcium intake at which urine calcium plus skin calcium losses were equal to the net absorbed calcium was rounded to 750 mg Ca as the requirement, which implied a recommended allowance of 900 mg Ca.

Conclusion: We conclude that the mean calcium requirement of adult men <60 y of age is 750 mg Ca/d, and the Recommended Dietary Allowance should be 900 mg Ca. Am J Clin Nutr 2011;93:442–5.

INTRODUCTION

The calcium requirement of humans has been a controversial issue for many years, but the modern history of the subject probably dates from 1962 when a Food and Agriculture Organization (FAO) Committee (1) recommended an allowance of 500 mg Ca/d largely on the basis of the seminal calcium balance studies of Malm on Norwegian prisoners (2), which emphasized the human body’s ability to adapt to low calcium intakes. There is no doubt about the value of Malm’s work, but with hindsight, it was perhaps misinterpreted or at least overinterpreted; the work took no account of insensible losses of calcium through the skin or of the very significant loss of bone that must have occurred during the long period of adaptation, which was only partial at best. Since then, Recommended Dietary Intakes (RDIs) of calcium for young adults have generally risen progressively to 1100 mg Ca, and all of these RDIs specify higher intakes for the elderly [FAO/World Health Organization (WHO) (3), United States and Canada (4), Australia and New Zealand (5), and Germany (6)]. The United Kingdom is the odd one out because its recommended allowance of 700 mg Ca for all subjects >19 y of age has remained unchanged since 1991 (7). In the final analysis, all of these figures, except for that of the United Kingdom, depend primarily on balance studies, and most of the studies were performed before or soon after the Second World War, with notional additions for skin calcium losses in some of them. None of the studies distinguished between the sexes, allowances for the elderly were very variable, and adjustments for skin calcium losses were uncertain.

The current article sought to provide an improved calculation of calcium requirement in adult men by restricting the analyzed balances to men ≤59 y of age and offering a firmer estimate of skin calcium losses.

METHODS

Selection of balances

We examined the age and sex composition of the 210 calcium balances that formed the basis of the FAO/WHO recommendations published in 2002 (3). The median age of subjects was 41 y, but the age range was 17–83 y, and all but 6 subjects were men. After removing the 6 women from the analysis and adding a further 15 balances on elderly men, we obtained 219 calcium balances in men derived from 9 published studies (2, 8–15). In these 219 studies, there was a very significant correlation between absorbed calcium (y) and calcium intake (x) according to the following equation:

\[ y = 0.259x + 219 \text{ mg} \quad (R^2 = 0.34) \hspace{1cm} (1) \]

To exclude an age effect, we plotted the residuals from this equation on age as shown in Figure 1. Inspection of the data showed an obvious fall in corrected calcium absorption in the 60...
men >59 y of age, and therefore these 60 balances were removed, which left 159 balances in men <60 y of age. One hundred fifty-seven of these balances were on calcium intakes ≤1033 mg Ca, but there were 2 outliers on intakes >1400 mg Ca that were removed, which left a reasonably homogeneous set of 157 balances in 72 men ≤59 y of age that we regarded as representative of adult men before ageing modulated the calcium requirement. The mean age of the remaining men was 38 y (range: 17–59 y), and the median duration of the balances was 107 d (range: 9–480 d). Ninety-nine of the balances were derived from Malm’s thesis (2). The four 9-d balances were included because they were preceded by a suitable equilibration period and were of high quality.

Skin calcium losses

The FAO/WHO recommendations (3), and others derived from them (5), assumed skin calcium losses of 60 mg Ca/d on the basis of studies reported in an article by a Danish group (16), but the lead author of that work, Peder Charles, reported a technical fault in the study procedures and suggested that the true value of skin calcium losses was 30–40 mg Ca/d, which he authorized us to quote (personal communication to BECN, 2009). In seeking independent confirmation of this figure, we noted that insensible quote (personal communication to BECN, 2009). In seeking independent confirmation of this figure, we noted that insensible

Calcium absorption and excretion

Because calcium absorption is a function of 2 processes (ie, saturable, active transport and diffusion), it is not a simple linear function of calcium intake but has been shown to approximate a log-linear function in humans (3) and rats (20). Therefore, we calculated the net amount of absorbed calcium (ie, the difference between dietary and fecal calcium amounts) as a function of the logarithm of calcium intake and urine calcium as a linear function of intake, and then we determined the calcium requirement as the intake at which the absorbed calcium equaled the urine calcium plus a skin calcium loss of 40 mg Ca/d by iteration by Newton’s method (21).

Statistical analyses

Data were analyzed by simple linear regression and Student’s $t$ test to assess statistical significance in Minitab version 12 (Minitab Inc, State College, PA).

RESULTS

The essential calculations are shown in Table 1. The significant correlation between net absorbed calcium and calcium intake was not changed by the logarithmic transformation of intake, but the known physiology of calcium absorption and inspection of the data favored the log-linear function. Therefore, the absorbed calcium is shown as a function of ingested calcium in Figure 2 with the curvilinear plot calculated from the second equation in Table 1. This curvilinear plot is compatible with the gradual saturation of an active transport process and the continuing operation of a linear diffusion process.

The significant correlation between the urine calcium and calcium intake is shown in Figure 3 with the regression line described in Table 1. The data were widely scattered because of

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Equation</th>
<th>$t$ test</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net calcium absorbed</td>
<td>$0.414 \pm 0.028$ Ca intake</td>
<td>14.8</td>
<td>0.001</td>
</tr>
<tr>
<td>$R^2 = 0.59$</td>
<td>$-65.4 \pm 18$ mg Ca</td>
<td>3.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Net calcium absorbed</td>
<td>$210 \pm 14$ log Ca intake</td>
<td>12.8</td>
<td>0.001</td>
</tr>
<tr>
<td>$R^2 = 0.59$</td>
<td>$-1135 \pm 88$ mg Ca</td>
<td>14.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Urine calcium</td>
<td>$0.436 \pm 0.03$ Ca absorbed</td>
<td>14.1</td>
<td>0.001</td>
</tr>
<tr>
<td>$R^2 = 0.56$</td>
<td>$+114 \pm 7$ mg Ca</td>
<td>16.2</td>
<td>0.001</td>
</tr>
<tr>
<td>Urine calcium</td>
<td>$0.150 \pm 0.022$ Ca intake</td>
<td>6.7</td>
<td>0.001</td>
</tr>
<tr>
<td>$R^2 = 0.23$</td>
<td>$+104 \pm 14$ mg Ca</td>
<td>7.3</td>
<td>0.001</td>
</tr>
</tbody>
</table>

* Data were analyzed directly and after logarithmic transformation by simple linear regression, and significance was assessed by Student’s $t$ test.
variation in absorbed calcium to which urine calcium was strongly related (Table 1).

To arrive at the calcium requirement, we calculated the intake at which absorbed and urine calcium were equal from the equations in Table 1 and illustrated the results in Figure 1. The regression line is shown \( (R^2 = 0.23, P < 0.001) \).

DISCUSSION

There are several points that require discussion. The first points are age and sex. We separated men \( \leq 59 \) y of age from older men because of the evidence shown in Figure 1 that calcium absorption fell at some time after age 60 y, although we do not suggest that 60 y is the critical age; it is a conservative estimate. We also separated male from female studies to allow for the possibility that there may be a sex difference in calcium requirements (even before menopause) for which we have some preliminary evidence and which will be the subject of further analysis. We are aware that our calculated calcium requirement for adult men is essentially the same as that in a major study of 373 balances in 155 men and women aged 19–75 y (22), but we think this is probably fortuitous, and we noted the very large error on that estimate. The data from that study (22) are of interest but would, in our opinion, be more valuable if the male and female and pre- and postmenopausal data were shown separately. It is hard to believe that there is no change in calcium requirement at menopause in view of the fall in calcium absorption and rise in obligatory calcium loss that occur at that time (19).

The second point for discussion is our logarithmic transformation of calcium intake in analyzing the relation between calcium intake and absorbed calcium. This empirical procedure yielded a relation that was compatible with the physiology of calcium absorption, which involves a saturable active transport mechanism and a passive diffusion process. A curve-fitting procedure may be mathematically more elegant but is subject to greater error; we believe that ours is the best available solution at the current time.

Finally, there is the issue of insensible skin losses of calcium, which was initially ignored in the earlier literature and then estimated by crude methodology to be of the order of 150 mg Ca/d (23). It was later estimated by an isotopic technique to average 60 mg Ca/d (16) but has since been corrected to 30–40 mg Ca/d by the senior author of that study (Peder Charles, personal communication to BECN, 2009). We arrived at a similar figure by an entirely different calculation on the basis of current estimates of insensible water loss through the skin of \( \approx 500 \) mL H2O/d (17, 18), which would contain 30–40 mg ultrafiltrable Ca, which is the combination of the ionized fraction and the complexed fraction (19). With the use of 40 mg Ca as the skin calcium loss in adult men, the intake at which urine calcium plus skin calcium equals net absorbed calcium is \( \approx 750 \) mg, which we suggest is the mean calcium requirement of adult men. The normal convention is that the Recommended Dietary Intake or RDI is the mean requirement plus 2 SDs, which are assumed to be \( \approx 10\% \). This adjustment adds 150 mg Ca to the requirement and yields an RDI of 900 mg Ca. This value is a further refinement of the recommendation of 1000 mg Ca/d by most countries but substantially higher than the UK recommendation of 700 mg Ca/d, which has remained unchanged since 1991 (7), makes no allowance for calcium losses through the skin or obligatory loss in the urine, and is clearly out of step with contemporary thinking.

The authors’ responsibilities were as follows—BECN: conducted the primary collection of data and analyses and preparation of the manuscript; and HAM: assisted with analyses of data and preparation of the manuscript. Neither of the authors had a conflict of interest.

REFERENCES