Absorbability and utility of calcium in mineral waters

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ABSTRACT

Background: Calcium intake in North America remains substantially below recommended amounts. Bottled waters high in calcium could help close that gap.

Objectives: The objectives were to summarize and integrate published absorbability and biodynamic data concerning high-calcium mineral waters and to combine these data with hitherto unpublished analyses from my laboratory.

Design: The usual library database was searched. The absorbability of calcium from a high-mineral water labeled with tracer quantities of \( ^{45} \text{Ca} \) was measured in human volunteers as a part of an otherwise low-calcium test meal. Published reports that used differing load sizes and meal conditions were harmonized by making corrections based on published calcium absorbability data.

Results: All the high-calcium mineral waters had absorbabilities equal to milk calcium or slightly better. When tested, all produced biodynamic responses indicative of absorption of appreciable quantities of calcium (ie, increased urinary calcium, decreased serum parathyroid hormone, decreased bone resorption biomarkers, and protection of bone mass).


KEY WORDS Calcium, calcium absorption, mineral water, calcium bicarbonate, calcium sulfate, bone resorption

INTRODUCTION

It is generally recognized that an adequate calcium intake is important for skeletal health (1, 2) and that calcium may be beneficial to several nonskeletal body systems as well (3). As a result, where regulations have permitted, food and beverage manufacturers have marketed a still-growing variety of calcium-fortified products. At the same time a corresponding interest has occurred in naturally calcium-rich mineral waters as potentially useful sources of the nutrient. Several studies have reported on the bioavailability of the calcium in such waters (4–9), and one small meta-analysis was published that contains data published through 1998 (10). In general, the reports indicate good bioavailability for the calcium in high-calcium mineral waters, but the studies to date were done under a variety of conditions and used different test loads and various endpoints. Hence, it has been difficult to formulate a single evaluation that adequately summarizes the nutritive value of the wide variety of waters as a group.

The purposes of this report were 1) to pull together the published absorbability data available through 2005, paying particular attention to test conditions and load sizes and adding previously unpublished data from my laboratory; 2) to formulate, insofar as the data permit, an overarching evaluation of the waters as a group; and 3) to point to possibly important differences in waters relating to the counter-ion accompanying their calcium.

SUBJECTS AND METHODS

Literature search

The published medical literature was searched for all articles indexed under the terms “mineral water,” “calcium,” “calcium absorbability,” “calcium bioavailability,” and “mineral water and bone.” In addition, the reference lists of all identified articles, plus the meta-analysis of Böhmer et al (10), were perused for citations that might have been missed by the literature search. In general, the articles identified fell into 3 categories: 1) studies in which calcium absorption was quantified by using calcium isotopic tracers or which contained evaluable data for estimating absorption from postabsorptive serum tracer concentrations; 2) a single study in which calcium isotopes were used and serum concentrations were reported, but fractional absorption was not estimated; and 3) biodynamic studies that reported effects of ingestion of calcium-rich mineral waters on urinary calcium, on concentrations of calcium regulatory hormones and bone remodeling biomarkers, and on bone density.

Previously unreported calcium absorbability results

My laboratory measured the absorbability of the calcium in a previously untested water (Sanfaustino; Societa Europa Ricerche Mediche, Milan, Italy) by using methods identical to those used for another Italian high-calcium mineral water (5). Briefly, the test water was labeled with a submicrogram quantity of \( ^{45} \text{CaCl}_2 \) and allowed to equilibrate, sealed, for 17 h at 3 °C. The calcium content of the test water was verified in my laboratory by direct measurement, by using atomic absorption spectrophotometry. The test water was ingested at the midpoint of a low-calcium breakfast meal in adult women, and the absorption

1 From Creighton University, Omaha, NE.
2 Supported by Creighton University Research Funds and by Societa Europa Ricerche Mediche, Milan, Italy.
3 Reprints not available. Address correspondence to RP Heaney, Creighton University, 601 N 30th Street, Suite 4841, Omaha, NE 68131. E-mail: rheaney@creighton.edu.
4 Accepted for publication April 3, 2006.
fraction was calculated from measured values of the ingested tracer in serum calcium (11, 12). This study involved human subjects and was approved by the Creighton University Institutional Review Board. Each subject gave written consent. Relevant test conditions were as set forth in Table 1.

RESULTS

Bioavailability studies

All the identified studies in which calcium tracer-based methods were used for measuring calcium absorption fraction are assembled in Table 1. It lists the labeled calcium content of the waters, the principal anion associated with the water’s calcium, the load size at which absorption was tested, and the test condition (ie, on an empty stomach without food or as a part of a standardized test meal). Most pertinently, the reported (or calculated) absorption fraction for each study is given (Table 1). Note that the study by Bacciottini et al (4) reported an absorption fraction of 0.196, not the 0.464 fraction presented in Table 1. The reason for the difference is that Bacciottini et al (4) used an inappropriately small value for the volume of distribution of the tracer. All values are $\bar{x} \pm$ SEM.

A distinction is also made in Figure 1 (as does Table 1) among studies in which the water was ingested either as part of a standardized test meal or on an empty stomach without additional food. It has been noted elsewhere that calcium absorption is improved when the calcium source is ingested with food (14). The data assembled here are consistent with that experience. The study by Couzy et al (8) was performed without additional food, and, in the study by van Dokkum et al (6), mineral water bioavailability was assessed twice, once by itself and once with a pasta-containing meal. Mean absorbability at fasting was $\approx 20\%$ lower than absorbability with coingested food. Comparable data with and without food are not available for Couzy et al (8), but, as evident in Figure 1, measured absorption in that study was less than predicted for milk calcium ingested at the same load (but as part of a standardized meal).

Three of the published studies tested milk and mineral water in a crossover design (4, 5, 8) and at comparable calcium loads and meal conditions. They permit, hence, a more secure estimate of the absorbability of the mineral water source relative to milk. The pertinent data from those studies are summarized in Table 2, and

![Image](https://academic.oup.com/ajcn/article-abstract/84/2/371/4881820/download)

**FIGURE 1.** Fractional absorption data from 7 studies of high-calcium mineral waters. The regression line is plotted for historical data for milk calcium, ingested as part of a meal, and studied over a wide range of load sizes. It is the least-squares, best-fit line with its 95% confidence limits. (The actual data points to which this line is fitted are not shown.) Circles represent mean values in studies in which the water was ingested as part of a test meal, and triangles indicate studies in which the water was ingested fasting and without coingested food. Error bars for the individual studies are $\pm 2$ SEMs.
1.084 close to a value of unity (identical absorbability), and the for each study the mean quotient of measured calcium absorb-
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### Table 2
Absorbability ratios for calcium in high-calcium mineral waters and in milk

<table>
<thead>
<tr>
<th>Reference</th>
<th>Brand</th>
<th>Subjects</th>
<th>Water/milk</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heaney and Dowell (5)</td>
<td>Sangemini</td>
<td>18</td>
<td>1.129 ± 0.0565</td>
<td></td>
</tr>
<tr>
<td>Bacciottini et al (4)</td>
<td>Uliveto</td>
<td>8</td>
<td>1.093 ± 0.127</td>
<td></td>
</tr>
<tr>
<td>Couzy et al (8)</td>
<td>Contrex</td>
<td>9</td>
<td>0.985 ± 0.070</td>
<td></td>
</tr>
<tr>
<td>Weighted $\bar{x}$</td>
<td></td>
<td></td>
<td>1.084 ± 0.043</td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\) All values are $\bar{x} \pm$ SEM.

for each study the mean quotient of measured calcium absorb-

### DISCUSSION

As is evident from the data of Figure 1 and Table 2, the absorbability of the calcium in all mineral waters tested to date is comparable to the absorbability of calcium in milk when studied under similar conditions. This is consistent with the conclusion reached by Böhm et al (10) for data published through 1998. The counter-ion in most of the waters tested was bicarbonate, but data are available for 4 waters in which the counter-ion is sulfate. In one (6), the absorbability was less than that reported by other investigators for bicarbonate-containing waters. But it is doubt-

Thus, it seems safe to conclude both that the calcium in high-
calcium mineral waters is highly absorbable and that the counter-

It might seem, therefore, that high-bicarbonate water is to be preferred over high-sulfate water, other things being equal. How-

One possible limitation of the studies covered in this review is that all used an extrinsic isotopic tracer. Doing so assumes that the isotope added to the water as a dissociated ionic species exchanges completely with the various other calcium species that may be present in the water. Failure of the tracer to equilibrate fully, in applications such as those reported here, would result in overestimation of absorbability, as I have shown for other sources (34).
The standard method of validating this assumption is to compare the results of extrinsically labeled products with intrinsically labeled sources (35). Unfortunately, that is not feasible with natural calcium-rich waters, because prior introduction of isotope into the geologic formations that are the sources of the calcium in these waters is not possible. However, substantial reassurance that labeling is adequate in this instance may be provided by the complementary results reported from the biodynamic studies summarized in this review (15–24). Because the biodynamic methods are less sensitive than tracer-based measurement, the fact that these waters elevate urinary calcium detectably and reduce parathyroid hormone and resorption biomarkers measurably indicates at least that their calcium is sufficiently absorbable to have nutritional value, because it produces effects similar to those of food and supplemental calcium sources. Finally, although mineral water consumption can potentially account for a substantial fraction of total daily calcium intake (36, 37) and hence can help close the gap between recommended and actual calcium intakes (1), such a calcium source functions much like a supplement; ie, it basically provides a single nutrient (or at most 2 in the case of the bicarbonate-rich waters). By contrast, milk, the comparator source most widely used to evaluate the absorbability of other calcium sources, provides, in addition to its calcium, a broad array of other nutrients important for total body and skeletal health.

The author has no conflict of interest with respect to commercial entities producing mineral waters.

REFERENCES


