Lactose maldigestion is not an impediment to the intake of 1500 mg calcium daily as dairy products1–3

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ABSTRACT

Background: A National Institutes of Health consensus conference concluded that a daily calcium intake of 1500 mg reduces the severity of osteoporosis. Because dairy products are the main natural source of dietary calcium, a diet providing 1500 mg Ca must contain large quantities of dairy products. However, it is widely believed that the lactose content of these products will not be tolerated by persons with lactose maldigestion (≈30% of the adult US population).

Objective: We evaluated the symptoms of lactose maldigestion and digestion when the diet was supplemented with dairy products providing 1300 mg Ca/d.

Design: Sixty-two women (31 with lactose maldigestion and 31 without) were studied in a double-blind, randomized protocol. Symptoms were compared during 1-wk periods when the diet was supplemented with 480 mL (2 cups) milk, 56 g cheese, and 240 mL yogurt provided as conventional products (34 g lactose/d) or as lactose-hydrolyzed products (2 g lactose/d).

Results: Women who digested lactose reported no significant difference in symptoms between the 2 treatment periods. Women with lactose maldigestion reported significantly increased flatulence frequency and subjective impression of rectal gas during the period of high lactose intake; however, bloating, abdominal pain, diarrhea, and the global perception of overall symptom severity were not significantly different between the 2 treatment periods.

Conclusion: The symptoms resulting from lactose maldigestion are not a major impediment to the ingestion of a dairy-rich diet supplying ≈1500 mg Ca/d. Am J Clin Nutr 1998;68:1118–22.

KEY WORDS Calcium, lactose, lactose maldigestion, lactose intolerance, dairy products, milk, cheese, yogurt, women

INTRODUCTION

A recent National Institutes of Health consensus conference concluded that a calcium intake of 1500 mg/d reduces the incidence and severity of postmenopausal osteoporosis (1). Implementation of this recommendation requires the daily ingestion of 3–6 calcium-containing tablets, 5 glasses of fortified orange juice, or a diet that is naturally rich in calcium. Because dairy products are the main natural food source that contains appreciable calcium, a diet containing 1500 mg Ca must be rich in milk or milk products such as cheese and yogurt. However, milk also contains large quantities of lactose and ≈30% of the US adult population (and most of the world’s population) is lactose intolerant (2). It is commonly believed that the symptoms resulting from lactose maldigestion limit the ability of these subjects to ingest a dairy-rich diet. However, in a recent double-blind study, we found that persons with lactose maldigestion experienced negligible symptoms when they ingested 480 mL (2 cups) milk/d (560 mg Ca) (3). The objective of the present double-blind study was to determine whether persons with lactose maldigestion tolerated a dairy-rich diet providing ≈1500 mg Ca/d when the intake of dairy products was spread out over the day and a variety of dairy products was used.

SUBJECTS AND METHODS

Subjects

Sixty-two women took part in the study. Subjects were excluded if they had previously had gastrointestinal surgery, had significant intercurrent illnesses, had received antibiotic therapy within the past 2 mo, or had an allergy to aspartame, milk, yogurt, or cheese. By design, 31 subjects had lactose maldigestion and 31 did not; in each of these groups, ≈50% of the women were premenopausal. The mean (±SEM) ages of the digestion and maldigestion groups were 49.4 ± 2.4 and 46.9 ± 2.6 y, respectively. The mean ages of the pre- and postmenopausal women were 37.3 ± 1.5 and 59.8 ± 1.5 y, respectively. In the lactose maldigestion group, 9 women were Asian, 2 were African American, 5 were Hispanic, and 14 were white, of whom 4 were Jewish; all 31 women in the lactose digestion group were white. Before the study, 23 women in the lactose maldigestion group and 2 in the lactose digestion group believed that the ingestion of dairy products resulted in appreciable abdom-
inal symptoms. A dietary recall study indicated that the average weekly intakes of milk, yogurt, and ice cream, respectively, were 350, 90, and 45 mL for the lactose digestion group and 140, 55, and 40 mL for the lactose maldigestion group.

All subjects underwent breath-hydrogen testing to determine their ability to digest and absorb lactose. An increase in the breath-hydrogen concentration of >0.45 μmol/L (10 ppm) after the oral ingestion of a 250-mL aqueous solution containing 15 g lactose (0.18 mol/L) was used as the indicator of lactose maldigestion (4). The breath-hydrogen concentration was determined as described previously (5). Before the dairy supplementation period, subjects were informed of their lactose digestion status and that they may develop gastrointestinal symptoms because of lactose malabsorption. The protocol was approved by the Human Subjects Committee of the Institutional Review Board at the Minneapolis Veterans Affairs Medical Center. All subjects gave written, informed consent.

**Experimental design**

For a 1-wk period before dietary manipulation, all subjects rated the severity of a variety of symptoms twice daily. Then, in a randomized, double-blind, crossover protocol, the subjects received 1 of 2 dietary supplements for 1-wk periods: 1) 240 mL conventional, 1%-fat milk with breakfast and dinner; 1 serving (28 g) of a hard cheese at lunch and at dinner; and 240 mL low-fat, strawberry-flavored yogurt at lunch time or 2) 240 mL lactose-hydrolyzed, 1%-fat milk with breakfast and dinner; 1 serving (28 g) of a hard cheese at lunch and at dinner; and 240 mL low-fat, strawberry flavored, lactose-hydrolyzed yogurt at lunch. Subjects ingested their regular diets with the exception of the additional strawberry flavored, lactose-hydrolyzed yogurt at lunch time or conventional, 1%-fat milk with breakfast and dinner; 1 serving (28 g) of a hard cheese at lunch and dinner; and 240 mL low-fat, strawberry flavored, lactose-hydrolyzed yogurt at lunch. Subjects reported their ability to digest and absorb lactose. An increase in the breath-hydrogen concentration of >0.45 μmol/L (10 ppm) after the oral ingestion of a 250-mL aqueous solution containing 15 g lactose (0.18 mol/L) was used as the indicator of lactose maldigestion (4). The breath-hydrogen concentration was determined as described previously (5).

**Milk and yogurt preparation**

The lactose in fresh, low-fat milk was hydrolyzed by adding 1.07 g of a lactase preparation obtained from *Kluyveromyces lactis* (Lactaid Inc, Pleasantville, NY) to 1000 mL milk. Because this enzyme is inhibited by the acid pH of yogurt, an enzyme with a low optimum pH (lactase from *Aspergillus oryzae*) was used to hydrolyze the lactose in yogurt. The lactase-treated milk and yogurt were incubated for 48 h at 4°C (5). Residual lactose was assayed by an enzymatic method (Lactose/β-galactose test kit; Boehringer Mannheim Biochemical Inc, Indianapolis). Multiple analyses showed that this treatment reduced the lactose content to undetectable concentrations (<0.1 g/L) (5, 6). Because lactose hydrolysis results in a somewhat sweeter product, the nonhydrolyzed milk was sweetened with 0.80 g aspartame/L milk. Our previous, extensive taste-testing experiments showed that subjects could not distinguish aspartame-flavored milk from lactose-hydrolyzed milk (5). In addition, testing showed that the strawberry flavoring in the yogurt obscured any taste difference resulting from lactose hydrolysis.

**Reporting of symptoms**

The occurrence and severity of symptoms were self-rated by subjects on 2 occasions daily (for the periods from breakfast time to dinnertime and from dinnertime to bedtime) during the baseline and the 2 test periods. Bloating, abdominal pain or cramps, and subjective impressions of rectal gas excretion were ranked on a continuous scale from 0 to 5 as follows: 0 (no symptoms), 1 (trivial), 2 (mild), 3 (moderate), 4 (strong), or 5 (severe symptoms) (5). Two irrelevant symptoms (headache and fatigue) were similarly rated. The time of each bowel movement was recorded along with its consistency as follows: 1 (hard), 2 (normal), 3 (soft), or 4 (watery). Last, subjects meticulously recorded each passage of flatus as well as their subjective impression of whether the volume of gas passed was small or large (5).

**Posttreatment survey**

At the conclusion of the study, all subjects were asked the following questions: 1) During which treatment week did you experience the greatest overall severity of symptoms? 2) Did you expect more symptoms than you experienced? 3) Are you willing to continue to consume the dairy-rich diet to obtain 1500 mg Ca/d? 4) Would you prefer to take 3–8 calcium-containing tablets each day rather than consume the dairy-rich diet to obtain 1500 mg Ca?

**Statistical analysis**

Data for the scores of each individual symptom were analyzed by repeated-measures analysis of variance (ANOVA) separately for each regimen on each day of the study to evaluate the influence of time. Because no differences over time were observed for either regimen, the mean symptom score for each 1-wk treatment period was analyzed by repeated-measures ANOVA. Differences between treatments were calculated by paired *t* tests, and the *P* value was adjusted by Bonferroni’s correction.

Data are the mean ±SEM symptom score for each 1-wk treatment period. A binomial distribution was used to calculate the *P* value (two-tailed). In addition, because some data had a skewed distribution, a nonparametric test (Wilcoxon’s signed-rank test) was also used to analyze the significance of differences. The significance of differences in responses to the post-study survey was analyzed by using a chi-square test. Analyses were performed with SYSTAT (7) and SPSS (8).

The sample size of 31 subjects in the lactose maldigestion group was selected as follows. A 1-unit difference in a symptom was chosen to be clinically relevant. Based on the variability of symptoms observed in previous studies (SD of the mean = 0.85 on a scale of 0 to 5) (3, 5) and a power of 0.95, differences of ≥1 unit for an intolerance symptom would be indicative of a significant difference (*P* < 0.05) with a sample size >28 (9).

**RESULTS**

The symptoms reported by the subjects are summarized in Table 1. During the baseline period, there were no significant differences in any symptom between the digestion and maldigestion groups. In addition, for the lactose digestion group, no significant differences were observed for any symptom during ingestion of hydrolyzed lactose compared with conventional dairy products. For the lactose maldigestion group, there was a minor but significant increase in the frequency of daily bowel movements (from 1.6 ± 0.2 to 1.8 ± 0.2) and significant increases in the frequency of small, large, and total flatus passages and the subjective impression of rectal gas with the consumption of conventional dairy products compared with lactose-hydrolyzed
**TABLE 1**

Severity of symptoms reported by women in the lactose maldigestion and digestion groups at baseline and during the 2 treatment periods

<table>
<thead>
<tr>
<th>Symptom and group</th>
<th>Lactose-hydrolyzed dairy products</th>
<th>Conventional dairy products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gastrointestinal (average daily severity)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excessive gas</td>
<td>Maligestion</td>
<td>0.5 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td>Bloating</td>
<td>Maligestion</td>
<td>0.4 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>Maligestion</td>
<td>0.2 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.1 ± 0.03</td>
</tr>
<tr>
<td>Nausea</td>
<td>Maligestion</td>
<td>0.05 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.04 ± 0.02</td>
</tr>
<tr>
<td>Feeling of fullness</td>
<td>Maligestion</td>
<td>0.3 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.2 ± 0.1</td>
</tr>
<tr>
<td><strong>Gastrointestinal (frequency/d)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowel movement</td>
<td>Maligestion</td>
<td>1.3 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>1.3 ± 0.1</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>Maligestion</td>
<td>0.02 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.07 ± 0.05</td>
</tr>
<tr>
<td>Small flatus</td>
<td>Maligestion</td>
<td>7.6 ± 1.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>9.8 ± 1.6</td>
</tr>
<tr>
<td>Large flatus</td>
<td>Maligestion</td>
<td>3.0 ± 0.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>4.0 ± 0.8</td>
</tr>
<tr>
<td>Total flatus</td>
<td>Maligestion</td>
<td>10.6 ± 2.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>13.7 ± 1.9</td>
</tr>
<tr>
<td>Irrelevant (average daily severity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td>Maligestion</td>
<td>0.2 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.2 ± 0.04</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Maligestion</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>0.4 ± 0.1</td>
</tr>
</tbody>
</table>

<sup>a</sup> ± SEM; <sup>b</sup> n = 31 per group. Symptoms were rated on a continuous 6-cm scale: 0 cm = none, 0–1.5 cm = trivial, 1.5–3 cm = mild, 3–4.5 cm = moderate, and 4.5–6 cm = severe. Each flatus passage was recorded as large or small and bowel movements were assessed with regard to frequency, consistency, and straining. Means within a row with different superscript letters are significantly different, <i>P</i> < 0.05 (repeated-measures ANOVA).

Bone fractures are a common and serious health problem in the elderly (10). Much evidence indicates that the development of osteoporosis is, in part, related to inadequate calcium intakes and that a high calcium intake may slow the loss of bone mass observed in postmenopausal women (11). As a consequence, the recommended daily intake of calcium by postmenopausal women was recently increased from 800 to 1500 mg/d (1).

Dairy products are the major food source that naturally contain appreciable calcium. Therefore, if the intake of 1500 mg Ca/d is to be obtained from fortified foods, the diet must contain large quantities of dairy products. However, milk and milk products also contain lactose, a disaccharide that is malabsorbed by ≈30% of Americans and 75% of the world’s population (2, 12). The symptoms that may result from malabsorption of lactose (flatulence, bloating, abdominal pain, and diarrhea) have received enormous publicity both in lay and medical publications. As a result, the public is extremely knowledgeable about lactose-induced symptoms, and real or imagined problems after lactose ingestion cause many persons to shun dairy products. Other reasons for shunning dairy products include the fat and energy contents of some of these products, as well as a nonappealing taste. The avoidance of dairy products for any reason virtually guarantees inadequate dietary intake of calcium.

Unblinded studies suggested that small amounts of lactose, such as the 12.5 g in 240 mL milk (1 cup), cause symptoms in most persons with lactose malabsorption (13–15). However, blinded studies showed no significant difference in symptoms after the daily ingestion of 240 mL conventional milk compared with 240 mL lactose-hydrolyzed milk (5, 16–18). Recently, we...
reported that 240 mL conventional milk with breakfast and dinner was not associated with significantly greater symptoms than were observed with a similar volume of lactose-free milk (3).

The potential for lactose-induced symptoms varies among dairy products. Cow milk contains \( \approx 12 \) g lactose per 250 mL, whereas hard cheeses contain very little lactose \( \approx 1 \) g per serving (28 g) (2). However, most of the lay population and medical community incorrectly believe that cheese has a high lactose content. Yogurt is well tolerated because lactose is removed during fermentation and the yogurt organisms supply lactase, which is active in the small intestine (19).

The goal of the present study was to determine whether persons with lactose maldigestion would tolerate a diet containing 1500 mg Ca/d supplied primarily as dairy products if the dairy intake was spread throughout the day and a fraction was provided as yogurt and hard cheese. During the week in which the women consumed conventional dairy products, the diet contained \( \approx 34 \) g lactose/d; during the week in which lactose-hydrolyzed dairy products were consumed, the lactose intake was reduced to 2 g/d. Given that blinded studies showed no significant increase in symptoms with 12.5 g lactose/d (5, 16–18), symptoms from the 2 g lactose were expected to be negligible.

As expected, women in the lactose digestion group reported no significant difference in symptoms between the 2 treatment periods. The most important observation of this study was that the dairy-rich diet was also well tolerated by the lactose maldigestion group. Flatus frequency and the impression of rectal gas excretion were the only symptoms that were significantly increased during the high-lactose diet (Table 1). This increased flatulence apparently was not perceived to be a major problem, however, because a survey conducted at the end of the study showed that the global perception of overall symptom severity was not significantly different for the 2 treatment periods.

The lack of diarrhea in the lactose maldigestion group indicated that the colon removed the bulk of the osmolar load provided by the malabsorbed lactose. However, the slight but significant increase in the frequency of bowel movements with the lactose-rich compared with the lactose-hydrolyzed diet (1.7 compared with 1.5 times/d) suggests that the colonic removal of the lactose-derived solute was not complete. The excessive flatus observed with the lactose-rich diet indicates that the gas removal mechanisms were overwhelmed by the rate of gas production; however, this excess gas did not accumulate to the extent that subjects perceived increased bloating or abdominal pain.

A subtle malabsorption of carbohydrate has been reported to occur with aging (20), and it is commonly believed that lactose-induced symptoms increase with age. No association between age and symptoms was observed in the present study in that no gastrointestinal symptom was perceived as being more severe by the menstruating women than by the premenopausal group. Similar results were found in other studies (16, 21).

Supplementation of the diet of the lactose digestion group with dairy products did not result in a significant increase in the severity of any symptom over that noted at baseline. However, the lactose maldigestion group reported that the severity of nausea, fullness, and bloating were significantly increased over baseline both during the week of lactose-hydrolyzed products and the week of lactose-rich products (Table 1). We considered several potential explanations for this finding. The possibility that the lactose-hydrolyzed diet contained appreciable lactose can be excluded because repeated assays showed negligible lactose concentrations. In addition, flatus frequency, an objective measure of carbohydrate malabsorption, did not increase during ingestion of the lactose-hydrolyzed products, indicating that these products did not contain nonabsorbable carbohydrate (Table 1).

![FIGURE 1. Mean (±SEM) gastrointestinal symptoms and frequency of flatus reported by 31 women with lactose maldigestion during the baseline period (solid black bar), the first week of treatment with either dairy supplement (hatched bar), and the second week of treatment with either dairy supplement (stippled bar). Means with different superscript letters are significantly different, \( P < 0.05 \). All of the gastrointestinal symptoms shown were significantly greater in the first week than during the baseline period; during the second week, fullness was the only symptom that was significantly greater than at baseline.](https://academic.oup.com/ajcn/article-abstract/68/5/1118/4648643)
A second possibility is that components of dairy products other than lactose induce symptoms in lactase-deficient subjects, although we are unaware of such a phenomenon. Last, because the women in the lactose maldigestion group were informed that they might experience problems, their expectancy of symptoms could have influenced the symptoms reported during both dairy regimens. Supporting this concept is the finding that significant increases over baseline in bloating, abdominal pain, and nausea were reported only during the initial week of dairy product supplementation, independent of the lactose content of the supplement (Figure 1). Sixty-six percent of the women in the lactose maldigestion group reported in a poststudy survey that their symptoms were much less than expected. Presumably, realization of the minor nature of the symptoms during the initial week of dairy products resulted in a mind set that caused fewer symptoms to be reported during the second week.

We conclude that problems resulting from lactose maldigestion do not represent a major impediment to the intake of 1500 mg Ca/d as dairy products. However, the extensive publicity concerning the ill effects of lactose has resulted in a widespread belief that lactose malabsorption induces severe problems. In reality, it appears that symptoms due to underlying irritable bowel syndrome have been misattributed to lactose intolerance, and a major educational campaign will be required to reverse this misperception.

The cost of the dairy products needed to obtain ≈1300 mg Ca/d would be ≈$1.20/d compared with $0.15 to $0.50 for calcium tablets. However, because the dairy regimen provides 38 g protein and 2.5 MJ (590 kcal)/d, the expenditure for other dietary constituents would be reduced by ≈20–25%. Thus, the cost of the dairy regimen is not necessarily more than that of calcium supplements.

Because the bioavailability of calcium in milk and in calcium supplements is similar (22), the choice of a calcium source will be determined by individual predilections concerning the palatability of dairy products and natural compared with tablet sources of nutrients. At the end of our study, ≈50% of the women in both groups indicated a preference for the dairy-rich regimen over the calcium tablets. Further studies will be required to determine whether long-term acceptance and compliance is best obtained when calcium is delivered via unmodified dairy products, lactose-reduced dairy products, tablets, or a combination of these sources.

REFERENCES