Vitamin D Status Is Positively Associated with Calcium Absorption among Postmenopausal Thai Women with Low Calcium Intakes1,2
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Abstract
Background: Few data exist on the ability of postmenopausal women to absorb calcium from diets habitually low in calcium.
Objective: The objective of this study was to evaluate fractional calcium absorption from a green leafy vegetable vs. milk in relation to vitamin D status.
Methods: We measured fractional calcium absorption from both a dairy- and plant-based source in 19 postmenopausal Thai women (aged 52–63 y) with low calcium consumption (350 ± 6207 mg/d) in relation to serum parathyroid hormone (PTH) and serum 25-hydroxyvitamin D [25(OH)D]. Fractional calcium absorption was measured using a triple stable calcium isotope method based on isotope recovery in a 28-h urine collection. Two extrinsically labeled test meals were ingested in random order: a green leafy vegetable (cassia) ingested along with 43Ca or a glass of milk containing 44Ca. Women received intravenous 42Ca with the first test meal.
Results: In 19 postmenopausal women studied (mean age, 56.9 ± 3.4 y), ~95% were 25(OH)D sufficient (>20 μg/L). Serum 25(OH)D status was positively correlated with fractional absorption from both cassia (P = 0.05, R² = 0.21) and milk (P = 0.03, R² = 0.26). Fractional calcium absorption from cassia was significantly lower than that measured from milk (42.6% ± 12.3% vs. 47.8% ± 12.8%, P = 0.03), but true calcium absorption did not significantly differ (120 ± 35 mg/d vs. 135 ± 36 mg/d). Serum PTH was significantly inversely associated with serum 25(OH)D (P = 0.006, R² = 0.37) even though PTH was not elevated (>65 pg/mL).
Conclusions: These findings suggest that vitamin D status is an important determinant of calcium absorption among Thai women with low calcium intakes, and cassia may be a readily available source of calcium in this population. Furthermore, these data indicate that serum 25(OH)D concentrations may affect PTH elevation in postmenopausal women with low calcium intakes. This trial was registered at www.clinicaltrials.gov as NCT02291315. J Nutr doi: 10.3945/jn.114.207290.

Keywords: calcium absorption, vitamin D, postmenopausal women, parathyroid hormone, bioavailability, stable isotope

Introduction
Osteoporosis is a widespread disease of public health concern that is characterized by reduced bone mass and poor bone quality. Although genetic factors strongly affect bone mass, optimal calcium absorption is also necessary to support normal skeletal consolidation and maintenance of bone mass (1). Age, dietary calcium intake, height (2), and estrogen status (3) have all been shown to influence calcium absorption in skeletally mature women. Calcium absorption is known to decrease with advancing age, decreasing on average by 3.6% for every 10-y increase in age in women across the ages of 8–82 y (4). Data from national surveys have shown that compared with US women aged ≥50 y (5), Thai women aged 40–80 y have a similar prevalence of osteoporosis at the femoral neck (13.6%) and lumbar spine (19.8%), with US women reporting an osteoporosis prevalence of 16% at either the femoral neck or lumbar spine (6). Both dietary and genetic factors affect bone mass. Variation in genetic polymorphisms of bone mineral density candidate genes between Asian and Caucasian women may affect osteoporosis risk differently in Asian women (7, 8).

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of lactose intolerance among the Thai elderly (11) and cultural dietary patterns that do not typically include milk-based products. National dietary calcium intake data from Thai women (aged 50–59 y) have typically reported low mean calcium intakes of 320 ± 44.6 mg/d (11).

In addition to the net amount of calcium in the diet, calcium bioavailability from individual foods plays a critical role in determining the amount of absorbed calcium that can be used for bone mineralization and maintenance (12). Many of the vegetables habitually consumed by Thai women contain high or moderate amounts of calcium (13), and these may provide alternative sources of calcium assuming they are consumed in adequate amounts and do not contain excessive amounts of inhibitors such as phytate and oxalate. At present, limited data on calcium bioavailability exist for commonly consumed Thai vegetables. Furthermore, the degree to which calcium absorption can be upregulated in response to low calcium intakes and in relation to vitamin D status in postmenopausal Asian women has not been well characterized.

Recent controversy exists on possible associations between vitamin D status and calcium absorption. Data in pediatric populations have largely concluded that there are no statistically significant associations between serum 25-hydroxyvitamin D (25(OH)D) and calcium absorption (14, 15). Similar findings have been reported in a randomized clinical trial of vitamin D supplementation and calcium absorption in 25- to 45-y-old US women (16) and other reports in North America and Australia have found associations (17, 18). Several studies have reported an inverse association between serum 25(OH)D and serum parathyroid hormone (PTH) in elderly populations (19, 20) but less data are available on this association in postmenopausal women from countries that have diets that are traditionally low in calcium.

The primary objective of this study was to measure fractional calcium absorption in postmenopausal Thai women from both milk and a commonly ingested green leafy vegetable (cassia) using a triple stable calcium isotope technique.

Methods

Subjects. Twenty-two healthy, postmenopausal women between the ages of 52 and 65 y were recruited from the community surrounding Bangkok and Nakhon Pathom, Thailand. Women were eligible for the study (NCT02291315) if they were healthy, at least 3 y postmenopausal, and did not have any diagnosed gastrointestinal or metabolic diseases known to interfere with calcium absorption and metabolism. Women taking medications (including thiazide diuretics, hormone replacement therapy, etc.) or dietary supplements (within 2 mo before the study) were not eligible to participate. The study was approved by the Committee on Human Rights Related to Human Experimentation, Mahidol University. Informed oral and written consents were obtained from all study participants.

Study design and sample collection. On the morning of the absorption study, fasting women (≥12 h) reported to the Human Metabolic Research Unit (HMRU) at Mahidol University. On arrival, baseline height, weight, and blood pressure were obtained and a fasting blood sample (10 mL) was collected. After emptying their bladders, each woman received 2 mg of 44Ca intravenously (in 5 mL of isotonic saline) over 5 min before being randomly assigned to receive 1 of the 2 extrinsically labeled test meals for breakfast and lunch, respectively. Extrinsic labeling of the plant and dairy source tested was used instead of intrinsic labeling because of feasibility and affordability. Intrinsic vs. extrinsic testing of milk has been tested and validated (21). Although extrinsic labeling of plant sources has limitations, this approach has been widely used in mineral bioavailability studies (22–24). Test meal 1 (milk meal) consisted of ~100 mg of fresh ultrahigh-temperature whole milk (Thai Denmark brand), to which 2 mg of 42Ca was extrinsically added and allowed to equilibrate for 12 h before ingestion. To approximate a standard Thai breakfast, a small amount (90 g) of cooked white rice was then consumed. Test meal 2 (cassia meal) consisted of 142 g of cooked cassia to which 1 mg of 43Ca was extrinsically added and thoroughly mixed. The cassia was also ingested along with 90 g of cooked white rice. Syrings containing all doses were pre- and postweighed. After the tracer foods were ingested, the empty glass and bowl were rinsed with deionized water and the rinse was also consumed to ensure the entire isotope was delivered. On day 1, a standardized dinner (rice, pork, soups, and vegetables) and snack were provided to all women. All urine was collected over the 28-h period postdosing (collection stopped 24 h after the second test meal was ingested). Women remained in the HMRU as inpatients until this collection was completed. On day 2, the women received a Thai breakfast (shrimp dumplings), snack, and lunch (soup, spaghetti, chicken, and vegetables). This dietary intake was standardized to control for dietary intake over the urine collection period. Triplicate aliquots of the diet were collected for determination of calcium and sodium content. The Thai INMUCAL computerized program (Windows version 1, 2006; developed by the Institute of Nutrition, Mahidol University) was used to obtain the 24-h nutrient content of the diet on the study day. Urinary sodium concentration was analyzed at the Mahidol HMRU using flame photometry (Corning Flame Photoauto Model 410 C; Sherwood Scientific, Ltd.).

Preparation of cassia. Cassia, a green leafy vegetable (Cassia siamea Lam.), was selected because this vegetable is commonly consumed by postmenopausal women in Thailand. The calcium content of this leafy vegetable is known to be relatively high whereas the phytate and oxalate contents are low compared with other Thai vegetables (13). For bulk preparation, ~10 kg of cassia leaves were washed and rinsed with deionized water before air-drying. The edible portion of the vegetable was then isolated and weighed. The cassia was blanched twice in boiling deionized water (the ratio of vegetable:deionized water was 1:5), and then cooled and weighed. This cooking method is generally used to reduce the bitter flavors of this vegetable. The boiled cassia leaves were homogenized and an aliquot was set aside for calcium analysis. Total calcium content of the cassia was determined using atomic absorption spectrometry (AS-S-Varian Techron AA 20). Four samples of the prepared cassia leaves were lyophilized and used for phytate and oxalate analysis. The phytate content of inositol pentaphosphate and inositol hexaphosphate was determined by HPLC using a C18 column and a refractive index detector (25) following the method of Hotz and Gibson (26). The oxalate content of the lyophilized cassia leaves was analyzed using a published HPLC method in which total oxalic acid is analyzed with a UV detector at a wavelength of 210 nm (27). The chromatographic separation was performed on a Bio-Rad Aminex ion exclusion column, using an isocratic elution with 0.0125 mol/L of sulfuric acid as a mobile phase. The amount of total oxalic acid in each sample was determined against a standard calibration curve (10–500 μg/mL) and was expressed as milligrams of oxalate per 100 g of sample. All samples were extracted and analyzed in duplicate.

Calcium, phytate, and oxalate in cassia leaves and test meals. The milk test meal and cassia test meal provided a total of 100 mg of calcium each, with the rice component contributing only negligible amounts of calcium (<2 mg). The 24-h intake of calcium on the day the test meals were ingested provided a total dietary calcium intake of 286.4 mg/d. Each cassia sample contained minimal amounts of phytate and oxalate, 4.2 ± 0.7 mg/100 g and 113 ± 22 mg/100 g, respectively, values that are relatively low when compared with other Thai vegetables (13).

Analysis of biochemical indicators. Analyses of serum PTH and urinary β-CrossLaps (a marker of bone resorption) were conducted using an ELISA (Roche) and serum 25(OH)D was analyzed via chemiluminescence.
and milk meals could be detected using a paired 14.5% difference in fractional calcium absorption between the cassia while adjusting for BMI and age. With a sample size of 19 women, a and calcium absorption were analyzed using linear regression models cumulative oral tracer recovery to the cumulative intravenous tracer Fractional calcium absorption was determined as the ratio of the measured using atomic absorption spectrometry (AAnalyst 800). Isotopic composition of final tracer solutions was validated by magnetic sector thermal ionization mass spectrometry (Triton TI; Thermomass).

Identified, coded urine samples from the absorption studies were sent to Cornell University for analysis with all subject identifiers removed. Calcium isotope ratios were measured in each of the 3 urine pools (U1, U2, and U3) and a composite 24-h pool made from timed collections over the study period. In each collection pool urinary calcium was precipitated using ammonium oxalate and precipitate was ashed in a muffle furnace and reconstituted in 3% ultrapurie nitric acid (JT Baker). Approximately 10 mL of the nitric acid solution was heated onto a rhenium filament, and the ion intensities of the calcium isotopes were measured. A ratio was made between each administered calcium isotope (\(^{42}\text{Ca}\) and \(^{43}\text{Ca}\) and \(^{44}\text{Ca}\) to \(^{40}\text{Ca}\) using magnetic sector thermal ionization mass spectrometry. Ratios were corrected for isotopic fractionation by normalizing the data to the \(^{40}\text{Ca}\) ratio. The mean relative SD for the stable calcium isotope ratios were as follows: \(^{42}\text{Ca}:^{40}\text{Ca} = 0.42\%\), \(^{43}\text{Ca}:^{40}\text{Ca} = 0.35\%\), and \(^{44}\text{Ca}:^{40}\text{Ca} = 0.28\%\). Total calcium in the 24-h urine collection from each subject was measured using atomic absorption spectrophotometry (AAnalyst 800).

Calcium absorption calculations. Δ percent excess was calculated in each urine aliquot as the degree to which the measured calcium isotopic ratio was increased over the natural abundance calcium isotopic ratio. Fractional calcium absorption was determined as the ratio of the cumulative oral tracer recovery to the cumulative intravenous tracer recovery in the 24-h urine collection obtained postdosing for both the milk (\(^{44}\text{Ca}\)) and the cassia (\(^{43}\text{Ca}\)) test meals. True calcium absorption (\(\nu_p\)) over a 24-h period was calculated for each test meal (milk vs. cassia) as the product of fractional calcium absorption and the calcium content of each test meal. True calcium absorption over the 24-h period was calculated using the mean calcium absorption of the 2 test meals and the total 24-h calcium intake ingested. Mean fractional calcium absorption measured from both food sources observed in these women was also evaluated in relation to normative equations that have been previously published by Heaney et al. (3), which predict expected absorption in women based on age. This was performed to determine if the measured fractional calcium absorption in these postmenopausal Asian women was similar to that predicted from equations developed in postmenopausal US women or if the values obtained were higher as a result of the chronically low calcium intakes and/or other possible population differences.

The daily nutrient intakes of study subjects were estimated using a 3-d diet record obtained before entry into the study. Nutrient intake was analyzed using the INMUCAL program. For this Asian population, BMI categories were evaluated according to the WHO international classifications as normal weight (18.5–24.9 kg/m\(^2\)), overweight (25–29.9 kg/m\(^2\)), and obese (\(\geq 30\) kg/m\(^2\)) (28).

Statistical analysis. Possible correlations between biochemical measurements [PTH, 25(OH)D, and β-CrossLaps], subject characteristics, and calcium absorption were analyzed using linear regression models while adjusting for BMI and age. With a sample size of 19 women, a 14.5% difference in fractional calcium absorption between the cassia and milk meals could be detected using a paired t test and an expected SD of 10.6% (29), as reported in a similar dual isotope study among similarly aged women (power = 0.8, α = 0.05). In examining fractional absorption, a mixed model including test meal (cassia or milk) and the randomized order of ingestion (first or second test meal) as fixed effects and the subject identification as a random effect was used to determine if an order effect was present. In this model, age and BMI were explored as covariates. All analyses were conducted using JMP Pro 11.0 (SAS Institute, Inc.). Normality of residuals and homogeneity of variance were tested. Values with \(P < 0.05\) were considered statistically significant. Data are reported as the means ± SDs unless otherwise stated.

Results

Subjects. A total of 22 postmenopausal Thai women were enrolled in the study. Two subjects did not obtain complete urine collections postdosing and 1 withdrew from the study after becoming ill; therefore, data from 19 of the 22 subjects were available for the final analyses. General subject characteristics of the 19 women that completed the study are shown in Table 1. Women had not undergone a surgical oophorectomy and none had a history of traumatic bone fracture. The mean calcium intake at baseline obtained from the 3-d dietary records (Table 1) was similar to the national Thai mean (320 ± 44.6 mg/d) for women aged 46–90 y old (11, 30). Six subjects had a BMI in the normal range (BMI: 18.5–24.9 kg/m\(^2\)), 9 were overweight (BMI: 25–29.9 kg/m\(^2\)), and 4 were obese (BMI: \(\geq 30\) kg/m\(^2\)). The BMI distribution of this group of women is comparable with national data of similarly aged Thai women (11).

Biochemical analyses. All biochemical variables were normally distributed. The mean serum 25(OH)D concentration observed was 32.8 ± 8.6 ng/mL. Of the 19 women studied, 18 were vitamin D sufficient [25(OH)D concentrations of ≥20 ng/mL], and only 1 woman (5.3%) was at risk of inadequacy [25(OH)D between 12 and 19 ng/mL]. None of the women had elevated serum PTH concentrations (≥65 pg/mL). Despite adequate serum 25(OH)D concentrations, a significant inverse association was evident between serum 25(OH)D and serum PTH (Figure 1). Serum 25(OH)D was positively associated with age across the observed age range of 52–63 y (\(P = 0.01\), \(R^2 = 0.32\)) whereas serum PTH was negatively associated with age (\(P = 0.04\), \(R^2 = 0.23\)). Urinary β-CrossLaps concentrations were significantly negatively correlated with both weight (\(P = 0.0005\), \(R^2 = 0.52\)) and BMI (\(P = 0.006\), \(R^2 = 0.37\)).

Fractional calcium absorption. Mean fractional calcium absorption in the 19 postmenopausal women studied is presented in Table 2. Using paired analyses, fractional calcium absorption was significantly lower when the test meal was cassia compared with

| TABLE 1 Subject characteristics and biochemical indices in 19 postmenopausal women 

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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<tbody>
<tr>
<td>Age, y</td>
<td>56.9 ± 3.4 (52–63)</td>
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<tr>
<td>Weight, kg</td>
<td>63.5 ± 8.8 (42.5–80.3)</td>
</tr>
<tr>
<td>BMI, kg/m(^2)</td>
<td>26.4 ± 3.5 (18.5–31.7)</td>
</tr>
<tr>
<td>Overweight, %</td>
<td>47.4</td>
</tr>
<tr>
<td>Obese, %</td>
<td>21.1</td>
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<tr>
<td>Height, cm</td>
<td>157 ± 4.7 (147–163)</td>
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<tr>
<td>Daily calcium intake, mg/d</td>
<td>350 ± 207 (108–423)</td>
</tr>
<tr>
<td>Serum PTH, pg/mL</td>
<td>40.4 ± 11.1 (18.4–56.1)</td>
</tr>
<tr>
<td>Urinary β-CrossLaps, ng/mL</td>
<td>0.637 ± 0.223 (0.164–1.04)</td>
</tr>
<tr>
<td>Serum 25(OH)D, ng/mL</td>
<td>32.8 ± 8.6 (19.4–48.1)</td>
</tr>
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</table>

1 Values are means ± SDs (range), n = 19. PTH, parathyroid hormone; 25(OH)D, 25-hydroxyvitamin D.
PTH and fractional absorption. No significant association was observed between serum and the cassia test meals (P = 0.36). A significant interaction between the test meal that 90.3% of the variability in calcium absorption was caused by the 2 test meals was highly correlated within the same woman such that absorption from the same calcium load and diet was highly variable (42). The serum concentrations of 25(OH)D evident in this group of women using a chemiluminescence assay are comparable with the concentrations of 32.6 ng/mL reported in 98 postmenopausal Thai women using an RIA (31), but are higher than that reported among 93 Thai women (61–97 y of age) where 21.5% of the group had serum 25(OH)D concentrations <20 ng/mL as measured using RIA (32).

Despite the low prevalence of vitamin D insufficiency, a highly significant inverse association was found between serum PTH and 25(OH)D concentrations. Several studies in postmenopausal women worldwide have reported inverse associations between serum 25(OH)D and PTH (33, 34), whereas other researchers have not found any significant associations (35, 36). A study of 103 peri- and postmenopausal Gambian women ingesting low calcium intakes (300–400 mg/d) found elevated serum PTH under conditions of vitamin D sufficiency [25(OH)D > 30 ng/mL] compared with European women (5). We did not measure calcitriol in our study and do not know if this association was evident among these Thai women. Limited data on calcium absorption in the Thai population exist. A calcium isotope study examining calcium bioavailability using a single stable oral isotope in healthy, premenopausal Thai women (aged 20–45 y) also found that calcium absorption from brown beans or ivy gourd (2 other low-oxalate, green leafy vegetables) was not significantly different from calcium absorption from milk (37). The calcium absorption from cassia leaves in our study (42.6% ± 12.3%) was similar to the fractional calcium absorption reported from both the winged beans (39.1% ± 12.8%) and the ivy gourd (47.6% ± 10.9%). Also, calcium absorption from milk in the prior study was comparable with the mean calcium absorption found in this study (55.2% ± 11.9% vs. 47.8% ± 12.8%, respectively). This study and another (12) suggest that many Thai vegetables may provide bioavailable sources of calcium similar to that of milk.

Organic compounds commonly found in vegetables are known to inhibit calcium absorption. In this study, the total fractional calcium absorption from cassia leaves was significantly lower than that measured from milk. However, net true calcium absorption from cassia and milk, 122 mg/d vs. 137 mg/d, respectively, only differed by 15 mg/d, an amount that is unlikely to have physiologic importance. The minimal difference in fractional absorption of calcium found between milk and cassia (with an oxalate content of ~162 mg/serving) differs from the large negative impact on calcium absorption evident for high-oxalate vegetables such as spinach (~478 mg of oxalate per serving), where a nearly 50% difference in absorption between that reported from vegetables has been reported (5.1% ± 2.6% from spinach vs. 27.6% ± 8.8% from milk) (38). Although dark leafy green vegetables are known to be good sources of calcium, several studies have demonstrated that oxalate is the most effective inhibitor of calcium absorption. Our data support other findings that indicate that low-oxalate vegetables, such as kale, Chinese mustard greens, and Chinese cabbage flower leaves, may achieve fractional calcium absorption values comparable with those observed from milk (12, 39).

A significant positive correlation was noted between serum 25(OH)D and fractional calcium absorption from either test meal. Data on relations between serum 25(OH)D and calcium absorption in the literature are often conflicting. Prior studies in postmenopausal American and Australian women have found no relation between serum 25(OH)D and calcium absorption as measured using dual stable calcium isotopes (4) or single oral isotopes (40). In contrast, a study investigating interindividual variation in calcium absorption among US premenopausal women (n = 41) found that serum 25(OH)D was positively

**Figure 2** Serum 25(OH)D concentrations were significantly inversely associated with serum PTH concentrations at baseline in a group of 19 postmenopausal Thai women. PTH, parathyroid hormone; 25(OH)D, 25-hydroxyvitamin D.

In this group of Thai women ingesting dietary calcium intakes comparable with the mean reported for Thai women, vitamin D status had a significant impact on fractional calcium absorption (4). Calcium absorption from the same calcium load and diet was highly variable between subjects (28.9–64.9%) but calcium absorption between the 2 test meals was highly correlated within the same woman such that 90.3% of the variability in calcium absorption was caused by subject variability. A significant interaction between the test meal and the order in which it was ingested was detected within subjects (P < 0.0001) such that calcium absorption was significantly lower in subjects who consumed cassia first.

Serum 25(OH)D concentration was positively associated with the fractional absorption measured from both the milk and the cassia test meals (Figure 2A, B). In addition, a significant positive association was evident between urinary β-CrossLaps and fractional absorption from the milk test meal (P = 0.007, R² = 0.36). No significant association was observed between serum PTH and fractional absorption.

**Discussion**

In this group of Thai women ingesting dietary calcium intakes comparable with the mean reported for Thai women, vitamin D status had a significant impact on fractional calcium absorption (4). Calcium absorption from the same calcium load and diet was highly variable between subjects (28.9–64.9%) but calcium absorption between the 2 test meals was highly correlated within the same woman such that 90.3% of the variability in calcium absorption was caused by subject variability. A significant interaction between the test meal and the order in which it was ingested was detected within subjects (P < 0.0001) such that calcium absorption was significantly lower in subjects who consumed cassia first.

Serum 25(OH)D concentration was positively associated with the fractional absorption measured from both the milk and the cassia test meals (Figure 2A, B). In addition, a significant positive association was evident between urinary β-CrossLaps and fractional absorption from the milk test meal (P = 0.007, R² = 0.36). No significant association was observed between serum PTH and fractional absorption.

**Table 2** Fractional calcium absorption from milk and cassia in 19 postmenopausal women

<table>
<thead>
<tr>
<th></th>
<th>Milk</th>
<th>Cassia</th>
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<tr>
<td>Calcium content of test meal, mg</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Fractional absorption, %</td>
<td>47.8 ± 12.8</td>
<td>42.6 ± 12.3a</td>
</tr>
<tr>
<td>V6,12 from test meal, mg/d</td>
<td>135 ± 38.3</td>
<td>120 ± 34.9a</td>
</tr>
<tr>
<td>24-h Calcium intake, mg/d</td>
<td>137 ± 12.8</td>
<td>122 ± 12.3</td>
</tr>
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</table>

1 Values are means ± SDs, n = 19. 2Significantly different from milk values, P = 0.006 (paired t test). Ca, calcium intake; V6, true calcium absorption.

2 Fractional absorption × Ca.
associated with calcium absorption efficiency as measured with a single oral isotope (17). Studies examining calcium absorption efficiency in healthy adults consuming low-calcium diets (300 mg/d) (41) and elderly women consuming a high-calcium diet (~900 mg/d) (18) have also demonstrated increases in gut calcium absorption in the presence of elevated serum 25(OH)D. Despite these findings, most studies find no increase in intestinal calcium absorption as a function of serum 25(OH)D over a wide range of baseline concentrations (1).

Our study had several limitations. The serum 25(OH)D analyses obtained in this study were undertaken in a clinical core laboratory at a medical school in Bangkok using a chemiluminescence assay and were not undertaken with LC-MS/MS assays that are most sensitive for 25(OH)D assessment (42). In addition, the clinical laboratory in Thailand did not participate in an external program such as the Vitamin D External Quality Assessment Scheme, which is used to validate the reliability of 25(OH)D assays, and there was no external reference standard included in the analysis because these standards were not commercially available at the time the study was undertaken. Despite analytical limitations with the 25(OH)D assay used, significant associations were found between serum 25(OH)D and PTH as well as between serum 25(OH)D and fractional calcium absorption and a biomarker of bone turnover. Our results were obtained using extrinsic labeling, and we have made the assumption that the extrinsic tracer is adequately mixing with the components of the food to provide an accurate measure of bioavailability. Although this approach has a number of assumptions, it has been commonly used in various calcium bioavailability studies and has produced similar results to intrinsic labeling of some vegetable sources (43, 44) and for intrinsic vs. extrinsic labeling of milk (21).

Using the previously published equation by Heaney et al. (3) for predicting calcium absorption as a function of calcium intake in adult women consuming Western diets with a mean calcium intake of 682 mg/d, we would expect postmenopausal women to absorb 38% of the calcium from a 286.4-mg/d Ca load. This predicted value is lower than the nearly 50% fractional calcium absorption values obtained in these postmenopausal Thai women consuming mean calcium intakes of 350 mg/d. However, values obtained in our population are comparable with those previously reported among 5 postmenopausal Caucasian women (mean age, 73 y) when measured after a 2-wk period on a low-calcium diet (279 ± 64 mg/d) (4).

In the Thai population, the habitual ratio of calcium:phosphorus intake among postmenopausal women is lower compared with that of US postmenopausal women (0.53 vs. 0.72, respectively) (43). High phosphorus intakes may prevent increases in serum 1,25(OH)2D during periods of low calcium intake (46). Furthermore, low calcium and high phosphorus intakes have been shown to elevate serum PTH and fibroblast growth factor 23 (FGF23) (47), which have opposing effects on 1,25(OH)2D (48, 49). More data on interactions between calcium and phosphorus intakes are needed when assessing overall impact of habitual diet on calcium absorption and bone homeostasis in populations at risk of osteoporosis.

In this group of vitamin D–sufficient postmenopausal Thai women, serum 25(OH)D was significantly inversely associated with serum PTH and positively associated with fractional calcium absorption from both a milk- and a plant-based source of dietary calcium. In addition, we found that similar amounts of calcium were absorbed from either cow milk or a low-oxalate, green leafy vegetable. Because postmenopausal Thai women commonly consume diets that are low in calcium, promoting the consumption of bioavailable calcium-containing vegetables such as cassia in groups at high risk of developing osteoporosis, e.g., postmenopausal women and elderly populations, may help maintain bone health and reduce fracture risk. Further studies are needed to explore the observed associations between vitamin D status and calcium absorption in postmenopausal Asian women ingesting low calcium intakes.

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References


