Soybeans are a good source of bone-healthy nutrients. Epidemiological studies in Asia evaluating diets containing traditional whole soy foods show a positive association with bone mineral density and fracture protection. Smaller scale intervention studies in Western nations mainly feature isolated soy protein (SP) and purified or concentrated soy isoflavones (SI) rather than whole soy foods and they have produced inconsistent results. Consumption of SP does not alter calcium (Ca) retention even though urinary Ca excretion is less in diets with SP compared with proteins higher in sulfur-containing amino acids. SI, often consumed at higher concentrations than would be available in traditional Asian diets, are not yielding the type of incontrovertible evidence that might be expected in support of their benefit to bone health. This forces one to ask whether whole soy might provide a superior effect on bone.

**Abstract**

Soybeans are a good source of bone-healthy nutrients. Epidemiological studies in Asia evaluating diets containing traditional whole soy foods show a positive association with bone mineral density and fracture protection. Smaller scale intervention studies in Western nations mainly feature isolated soy protein (SP) and purified or concentrated soy isoflavones (SI) rather than whole soy foods and they have produced inconsistent results. Consumption of SP does not alter calcium (Ca) retention even though urinary Ca excretion is less in diets with SP compared with proteins higher in sulfur-containing amino acids. SI, often consumed at higher concentrations than would be available in traditional Asian diets, are not yielding the type of incontrovertible evidence that might be expected in support of their benefit to bone health. This forces one to ask whether whole soy might provide a superior effect on bone.

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**Soy as a source of bone-healthy nutrients**

Unlike soft tissue, the bony skeleton is a concentrated source of minerals. The bulk of calcium (Ca), phosphorus, and magnesium in the body is found in hydroxyapatite crystal lattices that, together with collagen, make bones and teeth exceptionally hard and strong. Collagen, a major structural protein, comprises 90% of the organic matrix of bone. Trace amounts of zinc, iron, and copper are necessary for bone and collagen synthesis. Vitamin K is important for post-translational carboxylation of the bone matrix protein osteocalcin, which is involved in bone mineralization and Ca ion homeostasis. Vitamin D-dependent Ca-binding proteins facilitate active Ca absorption. Bone is a living tissue and as such requires all essential nutrients (1).

Dairy foods are featured in the Dietary Guidelines for Americans primarily as a source of nutrients for bone health. Soybeans are also a good source of many bone-healthy nutrients. The concentration of Ca is much less than in cow milk, but Ca-fortified soy milk has comparable levels of many of the nutrients in milk important to bone, making it an excellent nutritional alternative to cow milk (Table 1). The Ca in fortified soy milk is as absorbable as the Ca in cow milk when the fortificant is Ca carbonate and somewhat less well absorbed if the fortificant is tri-Ca phosphate (Fig. 1) (3). Bioavailability was determined in young women from a serving containing 250 mg Ca using stable Ca double isotopic tracer methodology to determine fractional Ca absorption. Tri-Ca phosphate is much less soluble than Ca carbonate or the Ca in cow milk, which exists as casein micelles, Ca phosphate, and ionized Ca. Ca in Ca-fortified tofu has also been shown to be as bioavailable as cow milk in premenopausal white and Asian women (4).

Phytic acid is the principal storage form of phosphorus in plant tissues; it is highly concentrated in the hulls of seeds. Ca bioavailability from whole soybeans depends on the phytic acid concentration (5). Ca absorption was studied in premenopausal women from soybeans grown hydroponically on different levels of phytate to produce a range of phytic acid content while simultaneously intrinsically labeling with $^{45}$Ca. Fractional-Ca absorption from high-phytate seeds ($0.310 \pm 0.070$) was significantly less than from low-phytate seeds ($0.414 \pm 0.740$), but neither differed from the absorption from milk ($0.377 \pm 0.056$) (5).

The 2005 Dietary Guidelines for Americans Advisory Committee (6) recommends 3 cups of legumes/wk (~540 g/wk),
because they are a rich source of trace nutrients; they are also rich in diverse phytochemicals. This quantity of legumes in the diet provides >5% of vitamin E, copper, potassium, and α-linoleic acid and >10% of folate, phosphorus, magnesium, iron, zinc, protein, carbohydrates, and fiber.

Soybeans are a good source of dietary fiber and the shortfall nutrients magnesium, Ca, vitamin E, and potassium as well as iron, a nutrient of concern for some subgroups. Iron bioavailability from soybeans is relatively high (7,8), possibly because iron is largely bound to ferritin (9), which protects it from being chelated by phytate (10). Iron absorption from intrinsically labeled soybeans was 27% in women with marginal iron deficiency compared with 61% in a reference dose of ferrous sulfate (7).

Soy and Ca metabolism
Perturbed Ca metabolism underlies much of the pathological bone loss that predisposes individuals to fracture risk. Cumulative daily changes in Ca retention lead to changes in bone mass, mainly because over 99% of the Ca in the body is in the skeleton. Bone balance is the difference between bone formation rate and bone resorption rate. These processes can be monitored with Ca isotopic tracers and compartmental modeling coupled with metabolic balance studies.

Dietary protein increases urinary Ca excretion and this was assumed to result in negative Ca balance (11). The increased urinary Ca excretion is associated with sulfur amino acids that increase net endogenous acid that can increase osteoclastic activity and, therefore, bone resorption. Protein sources lower in sulfur amino acid content such as soybeans should decrease urinary Ca excretion compared with proteins higher in sulfur-containing amino acids like milk and meat protein. Using Ca isotopic tracers and balance studies in postmenopausal women, Spence et al. (12) compared Ca metabolism parameters in postmenopausal women fed soy protein (SP)4-rich diets with or without isolavones and dairy proteins during 3 interventions in a randomized-order, crossover design. Urinary Ca excretion was reduced (P < 0.01) by 40 mg/d Ca when women were fed soy compared with milk proteins. This renal conservation of Ca has been estimated to result in a protection against bone loss of 1%/y. However, endogenous fecal Ca increased so that there was no difference in bone deposition or resorption or net balance between soy- or milk-based diets. Similarly, whole body retention of 47Ca by postmenopausal women did not differ when fed high-isoflavone SP diets compared with meat (13). Si intake over a wide range, consumed as part of SP isolates, did not influence bone turnover in postmenopausal women (14); however, a higher dose of purified SI did reduce bone turnover by about one-fourth that of estrogen in postmenopausal women (15). These evaluations were performed via measurement of urinary excretion of 47Ca from prelabeled skeletons. Based on these studies, the ability of SP or SI to protect against bone resorption is debatable. Whole soy foods have not been studied by using these methods.

**The relationship of soy foods to bone health**
Soybeans are unique among legumes on account of the high concentration of estrogen-like isoflavones they contain, as well as the high quality protein they provide, and their healthful fatty acid profile. Most of the experimental research focusing on the potential benefits of soy on pathological bone loss in ovariectomized animals and postmenopausal women has involved the administration of isolated fractions of the soybean such as the protein or specific isoflavones. It is not uncommon for experimental animals to be fed a SP- or isolavone-enriched diet or to be injected with isolavone aglycones on a daily basis for the purpose of investigating outcomes in bone studies. In human trials, isolavones may be administered in the form of supplements or they may be frequently used as an additive or fortificant in processed foods such as snack bars, baked goods, or cereal products, albeit often at concentrations exceeding those achievable via a traditional East Asian diet. Overall, study results for the effects of soy on bone loss have not always been in agreement, causing some degree of uncertainty about potential benefits; this is likely attributable to inconsistent study designs incorporating various soy compositions. The potential of soy foods to attenuate bone loss and fracture risk when they are habitually consumed as a dietary component in Western populations has yet to be adequately investigated.

Whole soy and traditional soy foods consumed as dietary staples since ancient times throughout East Asia include edamame (immature green soybeans), nimame (cooked whole soy), tofu (fermented and nonfermented), tempeh, soy flour, miso (soybean paste), and natto (fermented soybeans) (16). These foods are not highly refined forms of soy; that is, they are not greatly diminished in soy constituents as a result of being prepared via methods involving repeated water or alcohol extractions that leach isolavones, sugar, and oligosaccharide

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**TABLE 1** Comparison of key bone nutrients in 1 cup (240 mL) 1% milk and Ca-fortified soy milk

<table>
<thead>
<tr>
<th></th>
<th>1% milk</th>
<th>Ca-fortified soy milk</th>
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<tbody>
<tr>
<td>Ca, mg</td>
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<td>301</td>
</tr>
<tr>
<td>Phosphorus, mg</td>
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<td>Magnesium, mg</td>
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<td>39</td>
</tr>
<tr>
<td>Vitamin D, μg</td>
<td>2.45</td>
<td>2.97</td>
</tr>
</tbody>
</table>

1 Adapted from (2).

**FIGURE 1** Fractional Ca absorption from fortified soy beverage compared with milk in young women. Adapted with permission from (3). Values are means ± SD, n = 20. Means without a common letter differ, P < 0.05.
Assessment of the effects of traditional and whole soy food consumption on hormone-linked bone loss or fracture risk is somewhat thwarted by issues related to consumer acceptance and long-term compliance in Western countries in which these foods are more likely to be considered novel and/or objectionably flavored due to the relatively short history of their utilization and unaccustomed palates. Epidemiological studies in non-Asian countries present problems for investigators in populations in which the estimated daily soy intake is typically low compared with common exposure levels in Asian diets (18). As a result, most of the data available on whole soy food consumption and bone status in postmenopausal women emanates from epidemiological studies in Asian countries where the range in habitual soy food intake is sufficiently broad enough to yield valuable information that more readily lends itself to statistical scrutiny. The most clinically relevant endpoint for assessing the effectiveness of a treatment for osteoporosis is fracture risk. Randomized controlled trials (RCT) designed to assess the antifracture efficacy of treatments require the recruitment of large numbers of participants and follow-up over a sufficiently long period of time. RCT are also expensive and effects may be moderated by the ethical requirement to ensure participants in the placebo and treatment arms alike receive adequate Ca and vitamin D (19). To date, 2 of the most compelling studies suggesting a possible osteoprotective effect of whole soy foods on fracture risk in large cohorts of women are longer term, population-based prospective health studies performed in China (20,21). A handful of other studies in Asian populations have also shown an inverse relationship exists between soy food intake and bone loss.

**Intake of soy foods and bone fracture risk**

The first of the large population-based, prospective, cohort investigations examining the relationship between soy food intake and fractures involved 24,403 postmenopausal women living in urban communities in Shanghai (20). Following a baseline survey, during which trained interviewers used prepared questionnaires to establish the sociodemographic circumstances, health, medical history, and anthropometric measurements as well as lifestyle and dietary characteristics of the study population, 2 biennial in-person surveys were conducted over a mean follow-up period of 4.5 y to document usual dietary intakes via a validated FFQ. The participants, all of whom had no prior history of fracture or cancer, were also asked to report and give details of any incident clinical bone fractures (excluding broken bones of the skull/face, fingers, or toes) that occurred during the study period.

A total of 1170 incident fractures was reported among the women during study follow-ups, including bone breaks at the wrist (17.6%), arm (15.1%), vertebrae (14.9%), ankle (13.1%), rib (7.0%), and hip (3.3%). After classifying participants according to quintiles of SP and isoflavone intake (Fig. 2A,B) and following adjustments for age and total energy intake as well as other multivariate confounders, inverse associations were identified for SP intake and fracture risk and for SI intake and fracture risk (all $P < 0.001$). It was also determined, via stratified analysis, that the negative association between fracture risk and SP intake was consistently more marked for women during the first 10 y of menopause. Although a highly significant association between soy consumption and fracture risk in an observational study is less likely to be accounted for entirely by alternative explanatory factors, an association ultimately lacks the totality of evidence to imply causality. For instance, the self-reported fracture events were not verified via medical records. It is also possible that in some cases, high-energy trauma could have been misrepresented as being attributable to osteoporotic bones or that undiagnosed low-impact spinal trauma may not have been accounted for. Despite some of the shortcomings inherent in this type of study design, the data obtained from the large number of postmenopausal women in Shanghai provides strong justification for further investigations of the potential link between whole soy foods and bone health.

The second large study that merits further attention be paid to the effects of soy foods on bone involves a cohort of 63,154 healthy Chinese Singaporeans consisting of 27,913 male and 35,241 female participants ranging in age from 45 to 74 y (21). This long-term prospective study examined gender-specific associations between soy food intake and the risk of hip fracture. FFQ were used to determine the intake of commonly consumed soy foods in the region by study participants; these included tofu (soybean curd), taupok (firm tofu pressed and fried), foopei (deep-fried tofu), foojook (dried tofu), tofu-far (tofu cooked with syrup) (22), and soybean drinks. Total soy consumption was estimated based on the conversion of all soy foods to tofu equivalents (TE). SP and isoflavone intake were also calculated. 

The strength of the soy exposure-fracture associations was determined by a hazard ratio and the results were based on quartile values for overall risk by gender. In the event of overall...
risk being significant for either or both genders, results were stratified by 0–5 y or >5 y duration of follow-up. A total of 276 hip fracture cases occurred in men and 692 incidents of hip fracture were identified in women during the study; these fractures were verified via access to medical records. After adjustment for multiple influential factors, women belonging to quartiles 2 through 4 had similar hazard ratios for TE (Q2–Q4 ranged from 49.4 to $\geq 145.1$ g/d, SP ($< 2.7$ to $\geq 7.6$ g/d), and SI ($5.8$ to $\geq 15.4$ mg/4187 kJ · d$)); however, participants in these quartiles exhibited 21–36% reductions in hip fracture risk (all $P < 0.036$) compared with women in the lowest quartile of each soy component investigated [TE: Q1 was defined as $< 49.4$ g/d, SP: $< 2.7$ g/d, and SI: $< 5.8$ mg/4187 kJ · d$]. The stratified analysis for women revealed that the association of soy intake with hip fracture risk was highly significant for participants followed-up for >5 y. There were no corresponding associations for soy intake in women over the shorter follow-up period of 0–5 y. In contrast to women, men exhibited no significant associations between TE, SP, or SI and hip fracture risk. The gradual and modest decline in endogenous sex hormone levels in men as they age and an inherent ability of the male gender to aromatize available testosterone to estrogen were hypothesized to provide men with a natural physiological advantage in maintaining their skeletal mass and a subsequent reduced risk of fracture compared with women. The male hormonal advantage may mitigate the potential impact of soy foods on bone and fracture risk in men. The potential for soy foods to affect the bone health of women may differ based on how much tofu, bean curd pudding, and soy milk was consumed. Not all researchers have limited their studies of the effects of soy consumption on bone health to postmenopausal women. Ho et al. (26) examined a cohort of 132 healthy Hong Kong women aged between 30 and 40 y who were followed for an mean period of 38.1 mo to determine the effect of a habitual intake of soy foods on the maintenance of peak bone mass in the spine. BMD of the lumbar vertebrae (L2–L4) was assessed via DXA at baseline and annually in 116 participants and at baseline and after 3 y in 16 individuals. A validated FFQ was utilized to estimate the regular dietary intake of soy foods over time. From this information, the mean ± SD of dietary SI was calculated based on how much tofu, bean curd pudding, and soy milk was reported to be in the diet, essentially because these items account for ~70% of total soy intake in the Hong Kong population. Participants belonging to the top quartile of SI intake (i.e. 15.16 ± 9.59 mg/d, range: 7.43–48.30 mg, $n = 29$) lost a lower percentage of spinal BMD throughout the observational study period ($\sim 1.10\% \pm 3.04\%$ vs. $\sim 3.54\% \pm 5.60\%$, $P < 0.05$) than those belonging to the lowest quartile (1.40 ± 1.21 mg/d, range: 0–2.96 mg, $n = 37$). SI intake remained significantly associated with spinal BMD after adjusting for factors such as physical activity and energy-corrected Ca intake, the latter of which is known to explain ~15% of the isoflavone effect on spinal BMD. The ability to maintain bone mass after reaching one’s BMD peak at ~30 y of

### Intake of soy foods and attenuation of bone loss

A Japanese population-based osteoporosis study was designed to investigate the association between habitual natto intake and bone mineral density (BMD) changes over 3 y in Japanese women ranging in age from 20 to 79 y (23). Natto is a traditional Japanese food made from small-sized natto soybeans that are fermented with Bacillus subtilis natto; it is customarily served on rice as a popular breakfast dish but may also be added to miso soup, salads, and a variety of other frequently consumed traditional Asian dishes. At baseline, 394 premenopausal women and 350 postmenopausal women were stratified into respective tertiles (T1–T3) based on habitual grams of natto consumed per week. Dual X-ray absorptiometry (DXA) was performed at baseline and after 3 y to obtain BMD measurements at the spine (lumbar vertebrae 2–4), total hip, femoral neck (FN), and forearm (i.e. distal third of the radius). Premenopausal women did not demonstrate any relationships between initial or follow-up bone parameters and natto intake. In contrast, postmenopausal women had a positive association between baseline natto intake (T1: 0 g/wk, T2: 40–160 g/wk, and T3: >160 g/wk) and total hip BMD ($P = 0.0034$); other sites examined showed no such relationship. Over 3 y, the mean rate of postmenopausal bone loss was attenuated in association with natto exposure at the FN ($P < 0.0001$) and forearm ($P < 0.0002$). However, only the decreased rate of FN bone loss remained associated with natto intake after adjusting for influential covariates (T3: $-0.4 \pm 0.3\%$/y BMD $< T1$: $-1.5 \pm 0.2\%$/y BMD and T2: $-1.3 \pm 0.2\%$/y BMD; $P = 0.0094$).

Natto is a remarkable whole soy food, not only because it is fermented and extraordinarily rich in readily bioavailable isoflavone glycosides, but it also contains exceptionally high concentrations of menadione or bacterially derived menaquione (870 mg/100 g natto). Menadione is a potent activator of osteocalcin, a Gla-containing protein influential to the growth of hydroxyapatite crystals in the bone matrix. Other researchers have presented data suggesting that habitual consumption of natto is an explanatory factor for the inverse association that exists between high circulating serum menadione levels and lower fracture risk in postmenopausal women in different geographical locations within Japan and abroad (24).

### Intake of soy foods and maintenance

Not all researchers have limited their studies of the effects of soy food consumption on bone health to postmenopausal women. Ho et al. (26) examined a cohort of 132 healthy Hong Kong women aged between 30 and 40 y who were followed for an mean period of 38.1 mo to determine the effect of a habitual intake of soy foods on the maintenance of peak bone mass in the spine. BMD of the lumbar vertebrae (L2–L4) was assessed via DXA at baseline and annually in 116 participants and at baseline and after 3 y in 16 individuals. A validated FFQ was utilized to estimate the regular dietary intake of soy foods over time. From this information, the mean ± SD of dietary SI was calculated based on how much tofu, bean curd pudding, and soy milk was reported to be in the diet, essentially because these items account for ~70% of total soy intake in the Hong Kong population. Participants belonging to the top quartile of SI intake (i.e. 15.16 ± 9.59 mg/d, range: 7.43–48.30 mg, $n = 29$) lost a lower percentage of spinal BMD throughout the observational study period ($\sim 1.10\% \pm 3.04\%$ vs. $\sim 3.54\% \pm 5.60\%$, $P < 0.05$) than those belonging to the lowest quartile (1.40 ± 1.21 mg/d, range: 0–2.96 mg, $n = 37$). SI intake remained significantly associated with spinal BMD after adjusting for factors such as physical activity and energy-corrected Ca intake, the latter of which is known to explain ~15% of the isoflavone effect on spinal BMD. The ability to maintain bone mass after reaching one’s BMD peak at ~30 y of

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age is generally considered as being important to fracture risk later in life, and long-term dietary SI intake appeared to be associated with less bone loss in this cohort of premenopausal Chinese women.

Other whole soy and traditional soy food data has been acquired from considerably younger Asian women that demonstrate site-specific, long-term positive effects on bone associated with traditional soy foods in the diet. SI intake, as a result of consuming soy foods, including whole soybean sprouts, soybean paste, and tofu, was assessed over 2 y in 34 Korean women residing in Seoul and ranging in age from 20 to 26 y (27). The dietary data collected via 24-h recalls at ∼4-mo intervals was subjected to correlation analyses with data for percentage change in BMD (%ΔBMD, g/cm²). Bone measurements collected at baseline, and thereafter annually, were used to calculate %ΔBMD at the lumbar spine (L2-L4), FN, Ward’s triangle (WT), and femoral trochanter. Soybean intake data were classified into 3 categories: intake in g/d, intake as a percentage of energy per day (%E/d), and a consumption rate, or the number of days soybean consumption was reported out of the total days of recall per person. By 2 y, the %ΔBMD for WT was positively correlated with all categories of soy intake (P < 0.01 for g/d and % E/d intakes; P < 0.05 for consumption rate) and correlated at the FN for % E/d and consumption rate (P < 0.05). Mixed-model analysis was used to determine that for every 1-mg increase in isoflavones in the diet as a result of consuming traditional soy foods, BMD increased at a rate of 0.26% and 0.31%/y for the FN (P < 0.05) and WT (P < 0.008), respectively, after adjusting for covariates. The absence of a significant correlation for soy intake and %ΔBMD at the lumbar spine and femoral trochanter was thought to be attributable to the relatively higher amount of cortical compared with trabecular bone at these sites in comparison to WT and the FN. Although the sample size of the study was small and the mean daily (± SD) soybean and total isoflavone intake was not high (39.1 ± 30.8 g and 7.96 ± 4.52 mg, respectively), the results are interesting enough to warrant further investigations, considering peak bone mass may be implicated at this life stage.

Potential confounding factors associated with the effect of soy on bone health

An interpretation of the bone effects of soy during RCT in Western populations is complicated by numerous factors that are not an issue in East Asian observational studies. Randomized interventions typically necessitate the sudden routine inclusion of a previously irregularly, or rarely consumed, soy component such as SP isolates or SI at relatively high levels. The question of effective dietary adaption arises for individuals unaccustomed to soy ingredients, but not for East Asian participants in epidemiological studies in which no adaption period is required and no interruption to lifelong dietary habits occurs. Furthermore, considering that a full bone remodeling cycle involving subsequent periods of bone cell quiescence, activation, resorption, reversal, and formation activity can take up to 9 mo or more to complete (28), any dietary, supplemental, or pharmaceutical intervention that does not persist for at least 1 full cycle can create a remodeling transient by disproportionately affecting a specific stage(s) of the cycle and not others. Shorter term interventions (<1 y), of which there are many in relation to soy component effects on bone (29), likely reflect temporary distortions in the bone remodeling process rather than informative steady-state effects.

Effects of soy foods on bone density and resistance to low-impact fracture(s) may be influenced by age, hormonal status, different levels of adaptation to soy intake, and the duration of soy intake. It may be less difficult to determine bone effects following a life-long intake of traditional soy foods compared with intermittent intakes of soy (e.g., heavy consumption of soy formula during infancy and no appreciable consumption during adulthood) or compared with no early exposure to soy followed by a sudden increase in various soy ingredients such as isolated isoflavones and/or SP after menopause. The type of whole soy foods most frequently consumed (e.g. fermented vs. nonfermented) and/or ethnicity may also affect outcomes. For instance, many traditional soy foods containing various forms of tofu provide an additional Ca boost in Asian diets that are not typically rich in the types of dairy products that represent the main source of Ca in Western populations. The Ca boost from tofu in Asian populations may accentuate the osteoprotective effect more in Asian than in Western populations. Soy consumption tends to be associated with a dietary intake that is higher in vegetables and lower in meat and saturated fats, factors that might confer added bone health benefits that are difficult to extricate from soy consumption itself.

Above all, it must be appreciated that traditional soy foods are comprised of a unique and complex blend of isoflavones, protein, lipids, vitamins, minerals, and other bioactive compounds that may act individually and/or synergistically to exert healthful physiologic effects. The amount of soy foods typically consumed in traditional Eastern diets generally provides moderate daily intakes of isoflavones and SP compared with many of the intake levels achieved via supplemental regimes or commercially enriched foods available in Western cultures that tend to focus more on the provision of quantities of individual soy components. Moreover, the serving sizes in Asian cultures compared with Western societies are much smaller; e.g., the typical serving size of tofu is 98 g in Western countries compared with 33 g in Japan (18). One could venture to hypothesize, based on the epidemiologic data obtained in relation to a moderate habitual consumption of whole soy foods in the East that supplying large amounts of soy components in excess of what might be customarily consumed via the inclusion of traditional soy foods in the diet, may not be necessary and may even be confounding with respect to evaluating any potential osteoprotective effects of soy. As little as 4.98–7.32 g/d of SP or more is associated with a significant reduction in relative fracture risk in postmenopausal women, regardless of whether they have been menopausal for <10 y or ≥10 y (Fig. 2A). Furthermore, consumption of between 21.16 and 32.39 mg/d of SI or more is associated with a relative reduction in fracture risk in postmenopausal women after adjusting for age and energy consumption or after multivariate adjustments including age, BMI, exercise, smoking, alcohol, diabetes, education, season, energy intake, and intakes of Ca, nonsoy protein, fruits, and vegetables (Fig. 2B). Disparate study designs and the wide variety and contrastingly high amounts and soy components used in human bone investigations in Western societies are tending to yield inconsistent results that are more perplexing than elucidatory. Perhaps we need to reassess our approach and ask ourselves if whole soy foods, consumed regularly as a part of a well-balanced diet, might offer benefits beyond those of single soy components.

The future begins in the past

Currently, the evidence suggesting that habitual consumption of soy foods benefits bone mass and contributes to fracture resistance in humans is promising but still somewhat preliminary at best. Based predominantly on long-term observational studies in Asian populations, the evidence appears to support a likely benefit of traditional soy food consumption on bone...
health in indigenous Asian races. Significant osteoprotective benefits appear to be limited to the female gender, particularly those in the early years of menopause, although this latter finding has not been entirely consistent across all population-based studies. More rigorous study designs are required to establish an irrefutable causal link. Currently in the United States there is a gaping hole in our knowledge of the effects of habitual consumption of whole soy on bone. Furthermore, no rigorous research has investigated the effects of traditional soy consumption on bone. Rather, we have opted to focus on supplementation or consumption of specific soy components for shorter term study periods. If we seek to derive the types of health benefits we presume Asian populations get from eating whole and traditional soy foods, maybe we should look to similar soy foods and consumption patterns as a more logical starting point rather than rolling the dice on individual soy components.

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Literature Cited