

Effects of Soy Foods in Postmenopausal Women: A Focus on Osteosarcopenia and Obesity

Sijia Tang, Yang Du, Chorong Oh, Jaekyung No*

Department of Food and Nutrition, Kyungsoong University, Busan, Korea

Chronic diseases in postmenopausal women are caused by rapid changes in hormones and are accompanied by rapid changes in body composition (muscle, bone, and fat). In an aging society, the health of postmenopausal women is a social issue, and people's interest in ingesting high-quality protein is increasing in order to maintain a healthy body composition. This review aims to summarize the efficacy of soy foods and their impact on body composition. The soy protein and isoflavones contained in soy foods can improve muscle and bone density quality and reduce body weight. It is considered a breakthrough in preventing osteosarcopenia and obesity that may occur after menopause.

Key words: Postmenopause, Body composition, Osteosarcopenia, Obesity, Soy foods, Isoflavones

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*Corresponding author
Jaekyung No

 <https://orcid.org/0000-0003-2433-346X>

Department of Food and Nutrition,
Kyungsoong University, 309 Suyeong-ro,
Nam-gu, Busan 48434, Korea
Tel: +82-51-663-4651
Fax: +82-51-663-4651
E-mail: jkno3@ks.ac.kr

INTRODUCTION

The body composition (BC) of postmenopausal women changes rapidly due to hormonal changes, including the loss of bone (osteoporosis) and muscle (sarcopenia), usually in the presence of increased adiposity and fat redistribution towards central-type obesity.¹⁻³ Osteosarcopenic obesity is a newly described syndrome describing coexistence of osteoporosis and sarcopenia with fat increase during aging (Table 1).⁴

Soy foods are currently the subject of extensive research, mainly because they are a unique and abundant source of isoflavones. Due to the limited public data on the soy-bone relationship, soy foods often exhibit a positive effect on bone health. A 3-year longitudinal study of 116 premenopausal Chinese young women 30–40 years of age showed that the consumption of soy foods has a potential effect on bone mass.⁵ Soy can also improve the metabolic health of

postmenopausal women.⁶ In laboratory animals, dietary soy protein intake is associated with obesity, decreased blood glucose and insulin, and improved lipid distribution and insulin sensitivity, so this shows that soy foods are effective in improving obesity.⁷⁻⁹ Although research on soy foods remains controversial,¹⁰ as a source of high-quality protein, it is important for maintaining BC in postmenopausal women.

DISEASES CAUSED BY CHANGES IN BODY COMPOSITION

The dangers of osteosarcopenia in postmenopausal women

Sarcopenia (loss of muscle mass and strength) and osteoporosis (bone loss) are the two most common chronic diseases in the elderly. Given the clear interaction between bone and muscle, this

Table 1. Disease syndromes in postmenopausal women⁴

Disease	Risk factor
Osteoporosis/osteopenia	Maternal history of hip fracture
Sarcopenia	Low albumin, stroke, hyperlipidemia
Osteosarcopenia (osteoporosis/osteopenia and sarcopenia)	Older age, female, high alcohol intake, oral glucocorticoids, menopause (females), low protein intake, low body mass index, current smoking status, low dietary calcium, low serum vitamin D, hyperparathyroidism, obesity, rheumatoid arthritis, living in residential aged-care facilities, chronic kidney disease, low mobility and function
Obesity	Ethnicity, reduced physical activity, reduced lean mass, reduced resting metabolic rate, genetics treatment with certain drugs e.g., steroids, insulin, glitazones
Osteosarcopenic obesity (osteoporosis/osteopenia and sarcopenia and obesity)	Aging, osteoporosis/osteopenia, sarcopenia, fat infiltration, fat redistribution

aging syndrome is defined as “osteosarcopenia” when osteoporosis and sarcopenia occur simultaneously.⁴ Currently, the incidence of negative consequences such as falls, fractures, loss of function, weakness, and mortality will increase.¹¹ Research by Hamad et al.¹² confirmed that the prevalence of osteosarcopenia in postmenopausal women is high. Some studies^{13,14} of preselected populations of female patients with hip fractures and falls have found that osteoporosis is more prevalent in patients with osteosarcopenia compared to those with non-osteosarcopenia. Comparing postmenopausal women with only sarcopenia or osteoporosis to postmenopausal women with osteosarcopenia, the latter suffers from poorer body function and a higher risk of fractures, reduced function, and death. Complications of osteopenia/osteoporosis and sarcopenia may increase the risk of early death.¹⁵

The risk of obesity in postmenopausal women

With the increase of age and the arrival of menopause, many postmenopausal women often develop obesity at the same time as the appearance of menopause syndrome. The cause of obesity after menopause is due to aging, decreased activity, reduced energy consumption in the body, and excess energy accumulated under the skin, and postmenopausal women have more total fat than premenopausal women.¹⁶ Postmenopausal women are 4.88 times more likely to develop abdominal obesity compared to premenopausal women.¹⁷ In addition, estrogen increases fat oxidation in skeletal muscles and inhibits fat formation in liver.¹⁸ Therefore, it can be expected that a lack of estrogen associated with menopause will lead to an increase in visceral fat mass, and increased fat in obesity will reduce bone density and increase the risk of osteoporosis. However, there is a contrary conclusion that¹⁹ fat mass is not an im-

portant predictor of bone mineral density (BMD), and whether obesity threatens BMD is still to be strengthened.

Overweight and obesity also increase the risk of death, especially waist circumference and body mass index are related to the mortality of postmenopausal women with heart disease.²⁰ Excess visceral fat is also an independent risk factor for cardiovascular mortality. Therefore, the maintenance of normal weight and avoidance of obesity in postmenopausal women are important measures to prevent chronic diseases. The adverse phenomenon of weight gain in postmenopausal women is not inevitable. These diseases can be effectively addressed by implementing the principles of a healthy lifestyle and using soy foods where appropriate and possible.

CHANGES IN BODY COMPOSITION DUE TO HORMONAL CHANGES

Hormonal fluctuations in postmenopausal women can lead to an increase in adipose tissue content, causing a change in the ratio of body fat percentage to lean body mass, leading to water loss and obesity.²¹ Compared with premenopausal women, postmenopausal women have higher obesity rate²² and experience symptoms of central obesity.²³ At the same time, the decrease of estrogen leads to the loss of BMD, which may directly affect the muscle tissue and thus increase the risk of osteosarcopenia.^{24,25} One of the most responsive pathways in musculoskeletal health is the mammalian target of rapamycin (mTOR), which is involved in several anabolic processes of skeletal muscle.²⁶ The stimulus upstream of mTOR is insulin-like growth factor 1 (IGF-1), which is considered to be essential for muscle growth and regeneration.²⁷⁻²⁹ The estrogen receptor works on muscle strength through the actions of estrogen and

IGF-1. Estrogen and IGF-1 have been shown to decrease with menopause, thereby increasing the levels of proinflammatory cytokines, leading to sarcopenia, and increasing the risk of physical disability through its role in muscle protein breakdown.³⁰⁻³² Therefore, a decrease in IGF-1 levels during menopause and a loss of the protective effects on estrogen circulating cytokines can accelerate the loss of muscle mass.³³

Postmenopausal osteoporosis affects 30% of women, and 50-year-old women have a 40%–50% chance of suffering from osteoporotic fractures for the rest of their lives.^{34,35} When the total BMD of the human body decreases during menopause, the loss of endogenous estrogen appears to have a greater negative impact on cancellous bone compared to cortical bone.^{36,37} Hormone replacement therapy (HRT) can increase muscle and bone mass and prevent bone fracture in postmenopausal women; however, it is currently not recommended for primary therapy for osteoporosis due to its harmful side effects.³⁸

CAN SOY FOODS IMPROVE BODY COMPOSITION?

Soy foods in postmenopausal women

The European Society for Clinical and Economic Aspects of Osteoporosis and Osteoarthritis recommends an optimal dietary protein intake of 1.0–1.2 g/kg body weight/day with at least 20–25 g of high-quality protein at each main meal, with adequate vitamin D intake at 800 IU/day to maintain serum 25-hydroxyvitamin D levels > 50 nmol/L as well as calcium intake of 1,000 mg/day. Alongside regular physical activity/exercise 3–5 times per week, this regimen can prevent the age-related deterioration of musculoskeletal health in postmenopausal women. Protein consumption is an important strategy to improve BC (loss of fat and muscle gain). Based on data from the United States Department of Agriculture Nutrition Database, we compared the nutrients of soy milk and milk (Table 2) and found that soy milk has (1) lower energy and (2)

richer protein and (3) contains a larger amount of unsaturated fatty acids, and (4) does not contain any cholesterol. Therefore, soy milk is more suitable for postmenopausal women who are prone to obesity, low muscle mass, and bone loss. Adding soy to milk can significantly increase muscle mass and strength.³⁹

The effect of soy foods on muscle and bone

Isolated soy protein (ISP) is a well-known supplement that has been reported to improve health, athletic performance, BC, and energy use. ISP also contains naturally occurring compounds including isoflavones and saponins, which have antioxidant, anti-inflammatory, immunomodulatory, anti-cancer, and cardioprotective properties.^{40,41} It also contains branched chain amino acids (BCAA), which may have a positive effect on body weight regulation and muscle protein synthesis.⁴² BCAAs are obtained from ISPs, accounting for approximately 35% of the amino acids necessary for skeletal muscle formation.⁴³ BCAAs have been shown to be the main carrier of amino nitrogen between visceral and peripheral tissues (including skeletal muscle), but more importantly they appear to be the most direct cause of muscle protein stimulation.⁴⁴ Therefore, consuming BCAAs as a nutritional supplement can improve athletic performance and prevent muscle mass loss due to aging and disease.⁴⁵

Soy contains phytoestrogens, whose chemical structure is very similar to that of human estrogen. Compounds called lignans and isoflavones in soybeans can mimic the sex hormone estrogen produced by the human body.⁴⁶ Studies have shown⁴⁷ that phytoestrogens can help prevent bone loss in aging women. Recent studies have shown that there is a positive correlation between habitual soybean intake and bone health in premenopausal women. Soy isoflavones have a bone-preserving effect on bone mass after ovariectomies.⁴⁸ A study of postmenopausal women in Japan reported a significant positive correlation between soy proteins or isoflavone intake and spinal BMD.⁴⁹ The mechanism by which soybeans may play a protective role is unclear. There is some suggestive evidence

Table 2. Comparison of the nutritional composition of soy milk and milk

Food name	Energy (kcal)	Protein (g)	Total fat (g)	Carbohydrate (g)	Calcium (mg)	Phosphorus (mg)	Cholesterol (mg)	Unsaturated fatty acid (g)	Magnesium (g)	Iron (g)	Calcium (g)	Niacin (g)	Folic acid (g)
Soy milk	54	3.27	1.75	6.88	25	0.64	0	1.362	25	0.64	25	0.513	18
Milk	61	3.15	3.27	4.78	113	0.03	10	1.007	10	0.03	113	0.089	5

that the high consumption of soybeans is related to the production capacity of equol, which is a metabolite of soy isoflavones and may have a beneficial effect on bone loss.^{50,51} These promising findings require further evaluation.

Women who drink soy milk one or more times per day are 56% less likely to develop osteoporosis than women who do not drink soy milk, which is comparable to that 62% of the risk reduction of osteoporosis by drinking milk one or more times a day.³⁸ Compared with milk-based protein, soy protein was found to have a greater effect on increasing serum IGF-1, especially in women who do not receive HRT.⁵² The effects of soy protein ingredients and estrogen receptors may improve discomfort in postmenopausal

women. Daidzein has been found to down-regulate ubiquitin-specific protease 19 expression through estrogen receptor β and increase skeletal muscle mass in young female mice.⁵³ Since IGF-1 is osteogenic and can stimulate muscle protein synthesis, we recommend that postmenopausal women eat more soy protein rich in IGF-1 to promote muscle regeneration and bone health, and improve their quality of life.

Effect of soy foods on obesity

Soybeans have a significant impact on improving the metabolic health of postmenopausal women.⁵⁴ Increasing soy protein intake can improve blood lipids and is inversely proportional to obesity.

Table 3. Summary of the soy protein research experiments

Author (year)	Study	Intervention	Treatment duration	Outcome measurement	Effect on outcome
Horiuchi et al. (2000) ⁵⁵	85 PW/Japanese	Subjects with normal lumbar spine bone mineral density (L2–4 BMD) were investigated by questionnaire, and the calculated daily energy, protein, soy protein, and calcium intake were obtained.		L2–4 BMD Urinary deoxypyridinoline	Positive correlation with soy protein intake ($\beta=0.225$, $P=0.04$) Negative correlation with soy protein intake ($\beta=-0.08$, $P=0.03$)
Zhang et al. (2005) ⁵⁶	24,403 PW (March 1, 1997–May 23, 2000)/Shanghai	Usual soy food intake	Biennial in-person	Risk factors of osteoporosis, the relative risks of fracture	After adjustment for age, major risk factors of osteoporosis, socioeconomic status, and other dietary factors, the relative risks (95% confidence intervals) of fracture were 1.00, 0.72 (0.62–0.83), 0.69 (0.59–0.80), 0.64 (0.55–0.76), and 0.63 (0.53–0.76) across quintiles of soy protein intake ($P<0.001$ for trend).
Aubertin-Leheudre et al. (2007) ⁵⁷	18 Sarcopenic-obese women	70 mg of isoflavones per day (44-mg daidzein, 16-mg glycitein, and 10-mg genestein)	6 mo	FFM MMI	The isoflavone group increased significantly appendicular ($P=0.034$), leg ($P=0.016$) FFM. The isoflavone group increased significantly MMI ($P=0.037$).
Choquette et al. (2013) ⁵⁸	70 Overweight-to-obese; body mass index, 32.2 ± 4.8 kg/m ² ; PW, 59 ± 5 years	(1) Placebo (n = 15), (2) isoflavones (n = 15), (3) exercise and placebo (n = 20), (4) exercise and isoflavones (n = 20)	6 mo	Leg press, bench press Leg relative strength and muscle quality in the legs Muscle mass index	Exercise produced 49% and 23% increases, respectively, in leg press and bench press 1RM ($P \leq 0.01$). Leg relative strength and muscle quality increased by more than 50% (both $P < 0.01$). Muscle mass index increased by 7% ($P < 0.05$) in both exercise groups only.
Keshavarz et al. (2012) ⁵⁹	24 Overweight and obese female adults	A diet with soy milk or a diet with cow's milk	4 wk	Waist circumference	Waist circumference was reduced significantly following the soy milk period.
Llaneza et al. (2011) ⁶⁰	87 Healthy obese PW	Daily oral intake of a soy isoflavones extract (Fisiogen) containing 200 mg of Glycine max	6 mo	Leptin TNF- α	Mean serum leptin levels declined. TNF- α levels declined.
Van Nielsen et al. (2014) ⁶¹	15 PW with abdominal obesity	One diet, protein of mixed origin; the other diet, soy meat analogues and soy nuts containing 30 g/day soy protein.	2–4 wk	Frequently sampled intravenous glucose tolerance test Total cholesterol	The soy-protein diet resulted in greater insulin sensitivity. Lower after the soy-protein diet compared to the mixed-protein diet.

PW, postmenopausal women; BMD, bone mineral density; FFM, fat-free mass; MMI, muscle mass index; RM, repetition maximum; TNF- α , tumor necrosis factor-alpha.

Soy proteins are associated with clinically significant weight loss. Studies in some obese animal models have shown that eating soybeans in a low-calorie diet can promote greater weight and fat loss,^{62,63} and that dietary soy protein intake is associated with improved obesity, decreased blood sugar and insulin, and improved lipid distribution and insulin sensitivity, so this shows that soy foods are effective in improving obesity.⁷⁻⁹ Liu et al.⁶⁴ found that isoflavone soy protein supplementation for 6 months reduced body weight and body mass index in the postmenopausal Chinese women with mild hyperglycemia. However, there are also studies⁹ showing that although soy isoflavone has a significant improvement trend due to its low heterogeneity, only genistein plays an important role in improving glucose metabolism. This demonstrates that the type of isoflavone seems to have a different effect on metabolism, requiring further investigation.

CONCLUSION

Over the past few decades, the consumption of dairy products has decreased, and has been replaced by soy foods for dairy products and widely used as a substitute beverage among people who avoid dairy products. Today, soy foods may improve the BC of menopausal and premenopausal women. To make it easier for readers to understand the benefits of soy foods for postmenopausal women, we have summarized some research experiments (Table 3) and proved that it not only delays the physical disabilities of menopausal women with osteosarcopenia and obesity, but it can also improve their muscle mass and bone strength to prevent the development of osteosarcopenia. In summary, this review focuses on the soy proteins and isoflavones contained in soy foods, which have an improved effect on osteogenesis and muscle growth while having an effect on weight loss and glucose metabolism. Although some studies have questioned the mechanism of the protective effect of soybean ingredients on certain metabolic diseases, it remains unclear and requires more future research.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

Study concept and design: all authors; acquisition of the data: ST; analysis and interpretation of the data: ST; drafting of the manuscript: ST; critical revision of the manuscript: all authors; statistical analysis: ST; obtained funding: JN; administrative, technical, and material support: JN; and study supervision: all authors.

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