Impact of Phytoestrogen-Rich Foods on Bone Mineral Density in Postmenopausal Women: A Study in Rural Shamli District

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ABSTRACT

This study investigates the impact of phytoestrogen-rich foods on bone mineral density (BMD) among postmenopausal women in the rural Shamli district. A total of 500 postmenopausal women, aged 45-65 years, were enrolled and divided equally into two groups: a control group (n=250) and an experimental group (n=250). The experimental group received a dietary intervention consisting of phytoestrogen-rich foods, specifically soybean and flaxseed, for six months, while the control group followed their regular dietary habits. Baseline and post-intervention assessments of BMD were conducted using dual-energy X-ray absorptiometry (DEXA), alongside dietary intake surveys to ensure compliance and analyze nutrient adequacy. The results revealed a statistically significant improvement in BMD in the experimental group compared to the control group, highlighting the potential role of phytoestrogens in mitigating bone loss in postmenopausal women. This study underscores the relevance of dietary interventions, particularly the inclusion of phytoestrogen-rich foods, in improving bone health in vulnerable populations. The findings provide evidence-based recommendations for incorporating such dietary strategies into community health programs to address osteoporosis and related health issues in postmenopausal women. Further research is recommended to explore long-term effects and establish standardized guidelines for phytoestrogen consumption.

Keywords: Phytoestrogens, Bone Mineral Density, Postmenopausal Women, Soybean, Flaxseed, Rural Health, Dietary Intervention

INTRODUCTION

Postmenopausal women experience a significant decline in estrogen levels, which is closely associated with reduced bone mineral density (BMD) and an increased risk of osteoporosis. This hormonal shift has made postmenopausal women a critical demographic in studies aimed at preventing bone-related health issues. Nutrition plays a pivotal role in maintaining bone health, and phytoestrogens, plant-derived compounds that mimic the activity of estrogen, have garnered considerable attention in this regard. Among phytoestrogen-rich foods, soybean and flaxseed have been extensively studied for their potential to mitigate the adverse effects of estrogen deficiency on bone health.

Several studies have highlighted the beneficial effects of phytoestrogens on bone health. For instance, Messina *et al.* (2010) reported that the isoflavones in soybeans could increase bone mineral density by enhancing bone formation and reducing bone resorption in postmenopausal women. Similarly, the lignans found in flaxseeds have shown promise in improving bone health by modulating hormonal levels and protecting against bone loss (Lydeking-Olsen *et al.*, 2004). However, despite these encouraging findings, the impact of phytoestrogen-rich foods remains inconsistent across populations, likely due to variations in dietary habits, genetic factors, and environmental influences.

The rural population, particularly in India, presents a unique demographic for such studies due to distinct dietary patterns, limited access to healthcare, and an increased prevalence of nutritional deficiencies. This study

aims to address the gap by evaluating the impact of phytoestrogen-rich foods on the bone mineral density of postmenopausal women in the rural Shamli district. By dividing the participants into control and experimental groups and introducing a six-month dietary intervention with soybean and flaxseed in the experimental group, this research seeks to establish a concrete relationship between phytoestrogens and bone health.

The current study draws on previous research while offering a localized perspective that could have significant implications for public health interventions. The findings aim to provide actionable insights into dietary strategies for improving BMD and overall health in postmenopausal women, especially in resource-limited settings.

METHODOLOGY

The study, conducted in the rural Shamli district of Uttar Pradesh, aimed to investigate the impact of phytoestrogen-rich foods on bone mineral density (BMD) in postmenopausal women. The research spanned from November 2018 to June 2021 and included a sample size of 500 postmenopausal women, divided into a control group (n=250) and an experimental group (n=250). Participants were recruited from six villages: Jhinjhana, Rangana, Vedkhari, Badhi Mazra (Shikandrpur), Agripur, and Alinagar, using a purposive randomized selection process.

Participant Demographics:

Participants were predominantly from the 55–60 years age group across all villages, with variations in representation among other age groups. For instance, in Jhinjhana, which had the highest number of participants (185), 36.22% were aged 55–60 years. Similarly, Rangana (120 participants) showed 34.17% representation in the same age group. In Vedkhari (90 participants), a significant proportion (30%) were aged 50–55 years, while in Badhi Mazra (50 participants), the majority were aged 55–60 years (28%). Agripur and Alinagar, with smaller sample sizes of 30 and 25, respectively, followed similar age patterns. The most common age of menopause across all villages ranged between 45–50 years.

Inclusion and Exclusion Criteria:

The study included women aged over 40 who had their last menstrual period at least 12 months prior and were willing to participate. Exclusion criteria included perimenopausal women, those on special diets, women who had undergone hysterectomy, and those with chronic diseases, to ensure a focused assessment of the postmenopausal population without confounding factors.

Data Collection and Intervention:

A structured questionnaire was employed to gather socio-demographic data, while BMD measurements were taken at the outset and after six months of intervention using a bone mineral density machine operated by a trained technician. The experimental group received a dietary intervention comprising phytoestrogen-rich foods, specifically soy and flaxseeds, incorporated into their diet for six months. The control group maintained their usual dietary practices.

Study Methodology:

The study was conducted in multiple phases. Initially, the baseline BMD of all participants was measured to establish a reference point. After implementing the dietary intervention for the experimental group, follow-up measurements were conducted to assess changes in BMD. The structured questionnaire facilitated the collection of data on variables such as age, menopausal history, and other socio-demographic factors and nutrition factor which were analyzed to correlate with BMD outcomes.

The study aimed to isolate the effects of phytoestrogen-rich foods by comparing changes in BMD between the experimental and control groups. This approach allowed for a controlled evaluation of the dietary intervention's effectiveness while accounting for regional and demographic variations.

Key Observations:

Across the villages, the majority of participants fell into the 55–60 years age group and had experienced menopause between 45–50 years. The diverse sample size across villages provided a robust basis for generalizing findings to the rural postmenopausal population of Shamli district.

This study design, incorporating random sampling, structured data collection, and pre-and post-intervention assessments, provided a comprehensive framework to evaluate the role of phytoestrogens in improving BMD in postmenopausal women.

RESULTS AND DISCUSSION

Table 1 provides an overview of socio-demographic characteristics of 500 postmenopausal women. The majority (35.7%) are aged 55-60 years. Most participants (73.6%) identify as Hindu, and 80.8% live in nuclear families. A significant portion (78.4%) are married, while 19.6% are widowed. Regarding education, 75.6% are illiterate, with only 2.8% achieving graduate-level education. In terms of occupation, 42.8% are housewives, followed by 34.8% engaged in agriculture. Socio-economic status varies, with 23.2% in the middle-income group and 21.6% in the lower-income bracket. Age at menopause predominantly falls between 45-50 years (57%). This data highlights low literacy levels, high

agricultural involvement, and a concentration of menopause onset in the mid-to-late 40s among rural postmenopausal women.

Table 2 presents the mean nutrient intake of individuals compared to the Recommended Dietary Allowance (RDA) for moderate activity, highlighting percentages of excess or deficiency. Energy intake averages 2262 kcal, slightly exceeding the RDA by 1.43%. Protein intake is marginally below the RDA, with a 1.2% deficiency. Fat intake is significantly higher than the recommended level, showing a 42.8% excess. Calcium intake falls short of the RDA by 5.2%, with an average of 568.3 mg. Iron intake exceeds the RDA by 2.8%, averaging 21.6 mg. These variations indicate areas of over consumption, such as fat, and slight deficits in protein and calcium, requiring adjustments for balanced dietary intake (Fig. 1).

Table 1 : General characteristic of the Post – Menopausal Women			
Sr. No.	Socio demographic variable	Category	Postmenopausal women (500) N (%)
1.	Age in year	45-50	10
		50-55	15
		55-60	35.7
		60-65	20
		65-70	14.2
		≥ 70	5
2.	Religion	Hindu	368 (73.6)
		Muslim	132 (26.4)
3.	Type of Family	Joint	96 (19.2)
		Nuclear	404 (80.8)
4.	Marital Status	Married	392 (78.4)
		Widowed	98 (19.6)
		Separated	10 (2)
5.	Education of women	Illiterate	378 (75.6)
		Primary	63 (12.6)
		High School	26 (5.2)
		Intermediate	19 (3.8)
		Graduate	14 (2.8)
6.	Occupation of women	Housewife	214 (42.8)
		Agriculture	174 (34.8)
		Labor	92 (18.4)
		Business	7 (1.4)
		Service	13 (2.6)
7.	Socio economic status	(Upper) >5156 Rs.	89 (17.8)
		Upper middle	106 (21.2)
		Middle	116 (23.2)
		Lower middle	81 (16.2)
		Lower	108 (21.6)
8.	Age at menopause	40-45	108 (21.6)
		45-50	258 (57)
		50-55	105 (21)

| Table 2 : Mean nutrient intake of post-menopausal women			
Nutrient	Mean±SD	RDA for moderate activity	% of excess or deficiency RDA
Energy (kcal)	2262±395.6	2230	1.43+
Protein (gm)	54.34±12.9	55	1.2-
Fat (gm)	35.7±10.6	25	42.8+
Calcium (mg)	568.3±172	600	5.2-
Iron (mg)	21.6±10.7	21	2.8+
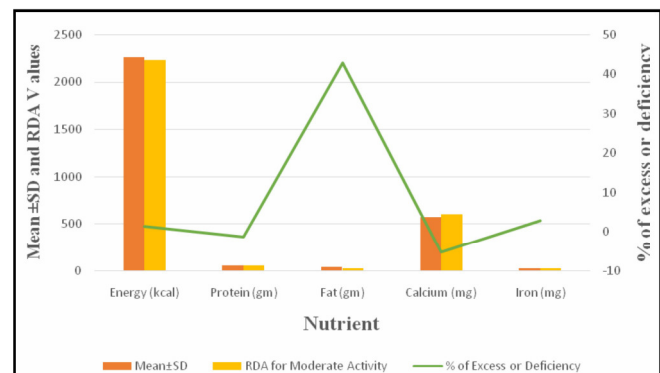
Fig. 1 : Comparison of Nutrient Intake with RDA

Table 3 highlights the results of a paired t-test comparing pre- and post-intervention bone density in experimental and control groups. In the experimental group, the mean bone density improved from -2.4918 (pre-intervention) to -2.2498 (post-intervention), with a decrease in standard deviation, indicating potential benefits from the intervention. Conversely, in the control group, the mean bone density worsened slightly from -

Table 3 : Comparison of Pre- and Post-Test Mean Bone Density Scores of Experimental and Control Groups Using Paired t-Test				
		Mean	N	Std. Deviation
Pair 1	Pre Exp B. Density	-2.4918	250	1.74329
	Post Exp B. Density	-2.2498	250	1.08692
Pair 2	Pre Con B. Density	-1.9460	250	.56317
	Post Con B. Density	-2.1877	250	.58280
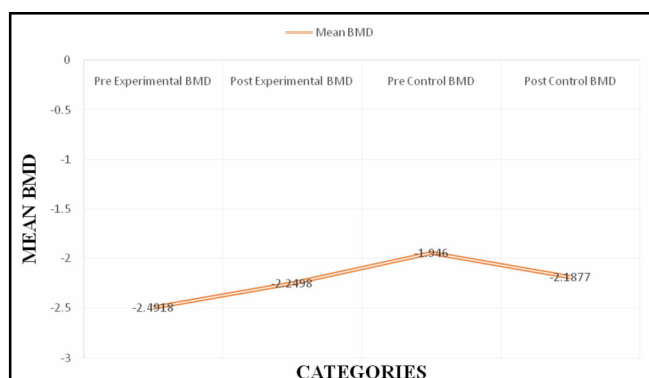
Fig. 2 :   Mean Bone Mineral Density (BMD)

1.9460 to -2.1877, suggesting a natural decline without intervention (Fig. 2).

These results align with literature indicating that phytoestrogens, such as isoflavones in soy, positively influence bone health in postmenopausal women by mimicking estrogenic effects (Setchell and Cassidy, 1999). The experimental group's improvement underscores the role of dietary phytoestrogens in mitigating bone density loss, a critical concern in postmenopausal osteoporosis management. The study affirms findings from prior research on the protective impact of phytoestrogens on skeletal health in hormone-deficient states.

Table 4 Presents paired samples correlations, comparing bone density measurements before and after interventions in two groups. For the experimental group (Pair 1), the correlation between pre-experimental and post-experimental bone density is very strong at 0.976, with a significance value of 0.000, indicating that the correlation is statistically significant. Similarly, for the control group (Pair 2), the correlation between pre-control

and post-control bone density is also strong at 0.953, with a significance value of 0.000, confirming statistical significance. Both results suggest a strong linear relationship between pre- and post-measurements within each group, indicating consistent trends in bone density changes over time. The high sample size of 250 further strengthens the reliability of these findings. This data highlights the impact of interventions in the experimental group and provides a benchmark comparison with the control group.

The study on the impact of phytoestrogen-rich foods on Bone Mineral Density (BMD) in postmenopausal women from rural Shamli provides critical insights into the dietary management of osteoporosis, a common concern in postmenopausal women. The statistically significant improvement in BMD observed in the experimental group corroborates the hypothesis that phytoestrogens positively influence bone health by mimicking estrogenic activity. The estrogen-mimicking properties of phytoestrogens, particularly isoflavones and lignans, act through estrogen receptor binding, leading to reduced osteoclastic activity and enhanced osteoblastic function. Isoflavones in soy are known to upregulate the expression of osteoprotegerin and downregulate receptor activator of nuclear factor-kappaB ligand (RANKL), thereby inhibiting bone resorption (Fitzpatrick, 2003). Similarly, lignans in flaxseed influence bone metabolism through antioxidant and anti-inflammatory pathways (Adolphe *et al.*, 2010). Messina *et al.* (2010), who reported that isoflavones in soy enhance bone health by stimulating bone formation and inhibiting bone resorption. Kanadys *et al.* (2021) confirmed that soy-based diets could significantly reduce the progression of osteoporosis in postmenopausal women by promoting bone mineralization and reducing bone turnover markers, Similarly, the lignans in flaxseed have demonstrated a potential role in modulating hormonal activity and reducing bone loss, as evidenced in studies by (Lydeking-Olsen *et al*., 2004; Dalais *et al.,* 1998). These findings suggest that phytoestrogens can serve as an effective dietary intervention in mitigating estrogen-deficiency-induced osteoporosis. The significant improvement in BMD in the experimental group (-2.4918 to -2.2498) compared

Table 4 : Correlation Analysis Between Pre and Post Bone Density Measurements in Experimental and Control Groups		N	Correlation	Sig.
Pair 1	Pre Exp B. Density and Post Exp B. Density	250	.976	.000
Pair 2	Pre Con B. Density and Post Con B. Density	250	.953	.000

to the control group underscores the role of dietary phytoestrogens in combating bone deterioration.Several studies have emphasized the efficacy of phytoestrogens in improving BMD. Setchell and Cassidy (1999) highlighted the estrogen-like properties of phytoestrogens, particularly isoflavones, in postmenopausal women. Despite these promising findings, discrepancies in the literature exist. A meta-analysis by (Sansai *et al.,* 2020) reported variability in BMD outcomes linked to dietary phytoestrogens, emphasizing the influence of factors such as dosage, duration, and population characteristics. This underscores the importance of tailoring dietary interventions to specific populations, as achieved in this study by focusing on rural postmenopausal women with distinct dietary habits and health profiles. Taku *et al.* (2010) demonstrated that soy isoflavone supplementation increased spine BMD by 1.03% after six months. The current study reinforces these findings and expands on them by providing evidence from a rural Indian population, which is often underrepresented in global research. The rural setting of the Shamli district presents unique challenges and opportunities. Nutritional deficiencies, lower literacy rates, and a high prevalence of traditional diets characterized by limited diversity are significant factors influencing health outcomes. The mean dietary calcium intake (568.3 mg) in this study was below the recommended dietary allowance (600 mg), emphasizing the critical role of phytoestrogen-rich foods in compensating for these deficits.The observed baseline calcium deficiency in the study population highlights a critical gap in nutrient intake, exacerbated by the limited dietary diversity in rural areas. Phytoestrogen-rich foods, when integrated into the diet, not only provide bioactive compounds but also contribute to overall nutritional adequacy. Consistent with the findings of Abdi *et al.* (2016), dietary phytoestrogens in conjunction with adequate calcium and vitamin D intake synergistically support bone health by promoting bone mineralization and reducing resorption. Additionally, the study's findings on fat intake exceeding recommended levels align with research by Kanadys *et al.* (2021)*,* which indicated that excessive fat consumption can adversely affect bone health by promoting inflammation and oxidative stress. This suggests the need for a holistic dietary approach that balances macronutrient intake while incorporating phytoestrogen-rich foods to optimize bone health outcomes. Additionally, the cultural acceptability of soy and flaxseed-based interventions in rural settings highlights the feasibility of incorporating these foods into local diets as part of community health initiatives.

Limitations and Areas for Further Research:

While the study provides robust evidence for the short-term benefits of phytoestrogen-rich foods on BMD, certain limitations warrant attention. The intervention lasted six months, and the long-term effects of phytoestrogen consumption remain unexplored. Additionally, variations in individual absorption and metabolism of phytoestrogens due to gut microbiota diversity, as highlighted by Atkinson *et al.* (2004), could influence the outcomes. Further research should focus on understanding these individual differences and establishing standardized guidelines for phytoestrogen consumption.

Implications for Public Health:

The findings have significant implications for public health, particularly in resource-limited settings. Dietary interventions involving phytoestrogen-rich foods like soy and flaxseed can serve as cost-effective strategies to combat osteoporosis. Incorporating these foods into government nutrition programs and rural health initiatives could help address bone health disparities among postmenopausal women. Furthermore, educational programs aimed at raising awareness about the benefits of phytoestrogens could enhance dietary compliance and improve outcomes.

Practical Considerations for Implementation:

The study demonstrated a strong linear relationship between pre- and post-intervention BMD in the experimental group, with a correlation coefficient of 0.976 (p < 0.001). This consistency indicates the reliability of phytoestrogens as a dietary intervention. However, ensuring accessibility and affordability of phytoestrogen-rich foods in rural areas is crucial. Policymakers must focus on integrating locally sourced soy and flaxseed into subsidized food programs to enhance their reach.

Conclusion:

The study demonstrates that incorporating phytoestrogen-rich foods like soybeans and flaxseeds significantly improves bone mineral density (BMD) in postmenopausal women in the rural Shamli district. Over a six-month intervention, the experimental group exhibited notable improvement in BMD, while the control group

experienced a decline, highlighting the protective role of phytoestrogens against bone loss. The findings underscore the potential of dietary strategies in mitigating osteoporosis, particularly in resource-limited settings. Despite socio-economic and educational challenges, the intervention's positive outcomes suggest that simple, accessible dietary modifications can offer substantial health benefits. This study advocates integrating phytoestrogen-rich foods into community health programs to address osteoporosis and enhance bone health in vulnerable populations. Further research is recommended to evaluate the long-term impacts and establish standardized dietary guidelines for phytoestrogen consumption in postmenopausal women. The strong statistical correlations reinforce the reliability of these results and provide a foundation for future public health interventions.

Conflice of Interest :

Financial Support:

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