

Impact of a Physical Exercise Regimen with Finger Millet Supplementation on Bone Mineral Density in Postmenopausal Women

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Abstract—Purpose: To evaluate changes in bone mineral density (BMD) following a three-month intervention combining a physical exercise regimen with finger millet supplementation among postmenopausal women. Design/methodology/approach: A quasi-experimental, one-group pre-test/post-test design was used. The study included 130 naturally postmenopausal women aged 45–55 years who were within two years of menopause. BMD was assessed by dual-energy X-ray absorptiometry before and after the intervention. The intervention comprised bone-health-oriented exercises and finger millet laddus provided as a dietary supplement. Findings: The proportion classified as having normal BMD increased from 30.8% before the intervention to 50.0% after the intervention, while osteopenia decreased from 42.3% to 38.5% and osteoporosis from 26.9% to 11.5%. Reported pre/post T-score comparisons were statistically significant ($p < 0.001$). Socioeconomic status, BMI, dietary habits and medical history were reported to be significantly associated with BMD score ($p < 0.05$). Originality: The study combines a locally available traditional cereal-based food intervention with a structured physical exercise programme in recently postmenopausal women, providing a community-oriented approach to bone-health promotion.

Index Terms—finger millet; bone mineral density; postmenopausal women; exercise; dietary supplementation; bone health

I. INTRODUCTION

Postmenopausal women are at increased risk of osteoporosis because declining oestrogen is associated with accelerated bone loss. Reduced bone mineral density (BMD) is an important determinant of fracture risk, making early identification and lifestyle-based prevention particularly relevant during the early postmenopausal period [1], [2].

BMD assessment provides an objective measure of skeletal health, and dual-energy X-ray absorptiometry (DXA) is widely used for clinical assessment. Previous research has also reported relationships between body composition and BMD in postmenopausal women [3], [4].

Physical activity, particularly weight-bearing and resistance exercise, can provide mechanical stimuli that support bone remodelling. Systematic reviews indicate that appropriately prescribed exercise can improve or preserve BMD in postmenopausal women [5]–[7].

Dietary calcium and other nutrients are also important for skeletal health. Finger millet (*Eleusine coracana*) is a traditional cereal with appreciable mineral content and has attracted interest as a food-based source of calcium and other nutrients [8], [9]. Studies have additionally described antioxidant and anti-inflammatory properties of finger millet varieties [10].

Evidence from a previous intervention involving physical activity and a finger-millet-based food supplement suggests potential benefits for BMD and biochemical parameters [11]. However, further community-based evidence in recently postmenopausal women is warranted. Therefore, the present study evaluated changes in BMD after a three-month combined physical exercise and finger millet supplementation intervention.

II. MATERIALS AND METHODS

A. Study Design and Setting

A quasi-experimental, one-group pre-test/post-test design was used. The study was conducted in a selected community area served by a Primary Health Centre (PHC) in Kumarapalayam, Puducherry, India. Data collection and the intervention were conducted over three months, from August 2024 to October 2024.

B. Participants

The study included 130 naturally postmenopausal women aged 45–55 years who were within the first two years after

menopause. Participants were required to be available during the data-collection period and able to communicate in Tamil or English.

Women receiving indigenous medicine or herbal treatment, hormone replacement therapy or anti-stress medication; those already participating in exercise or yoga programmes; those with sensory or cognitive impairment; and those with debilitating conditions or serious illness were excluded.

C. Ethical Considerations

The study protocol was reviewed and approved by the Institutional Ethics Committee (Approval No. IEC/C-P/63/2024) before commencement of the study. Written informed consent was obtained from all participants, and confidentiality was maintained throughout the study.

D. Data Collection and Outcome Measurement

Baseline demographic information included age, weight, height and other relevant demographic characteristics. Bone mineral density was assessed by dual-energy X-ray absorptiometry (DXA) before and after the intervention. BMD was classified according to T-score categories as reported in the study tables: normal (≥ -1.0), osteopenia (< -1.0 to > -2.5) and osteoporosis (≤ -2.5).

E. Intervention

The intervention had two components: a physical exercise regimen and finger millet supplementation. The exercise regimen included wall push-ups, heel raises with chair support, lunges, jump-and-land with a flat foot, figure-of-eight walking, and step-up and step-down exercises. Progressive muscle relaxation was included as a stress-reduction component.

Finger millet supplementation was provided in the form of finger millet sweet balls (ragi laddus). The preparation described in the study used 800 g finger millet flour, 400 g powdered jaggery and 300 g ghee. The flour was roasted in ghee for approximately five minutes, powdered jaggery was added, and the mixture was combined and divided into ten 150 g portions. The laddus were prepared fresh each week. The source manuscript reports that the product was certified by Chennai Testing Laboratory Pvt. Ltd., India, for food safety and quality. The intervention duration was three months. Exact exercise frequency, session duration, progression, supervision/adherence procedures and participant-level intake should be reported from the original intervention records to ensure reproducibility.

F. Statistical Analysis

Descriptive statistics were used to summarise participant characteristics and BMD measures. The manuscript reports pre- and post-intervention T-score comparisons using t statistics and chi-square statistics for associations between selected participant characteristics and BMD score. Statistical significance was set at $p < 0.05$. The reported statistical values should be verified against the original statistical output before submission.

III. RESULTS

A total of 130 postmenopausal women were included in the analysis. Fifty-five participants (42.3%) were aged 45–49 years and 75 (57.7%) were aged 50–55 years. The largest socioeconomic group was the middle category (38.5%). Most participants were overweight (46.2%), and 38.5% were classified as moderately active. Adequate calcium intake was reported for 38.5% of participants. Regarding time since menopause, 46.2% were within one year of menopause and 53.8% were within one to two years.

A. Participant Characteristics

TABLE I. DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF THE PARTICIPANTS (N = 130).

Variable	Category	n	%
Age	45–49 years	55	42.3
	50–55 years	75	57.7
Socioeconomic status	Low	40	30.8
	Middle	50	38.5
	High	30	23.1
	Very high	10	7.7
Religion	Hindu	50	38.5
	Muslim	40	30.8
	Christian	30	23.1
	Other	10	7.7
BMI	Underweight	5	3.8
	Normal	50	38.5
	Overweight	60	46.2
	Obese	15	11.5
Physical activity level	Sedentary	40	30.8
	Moderately active	50	38.5
	Active	30	23.1
	Highly active	10	7.7
Dietary habits	Low calcium intake	20	15.4
	Adequate calcium intake	50	38.5
	High calcium intake	40	30.8
	Very high calcium intake	20	15.4
Medical history (bone health)	No bone issues	60	46.2
	Mild bone issues	40	30.8
	Severe bone issues	20	15.4
	Osteoporosis diagnosed	10	7.7
Menopausal status	<1 year postmenopausal	60	46.2
	1–2 years postmenopausal	70	53.8

B. Bone Mineral Density Classification

TABLE II. BMD CLASSIFICATION BEFORE AND AFTER THE THREE-MONTH INTERVENTION.

BMD classification	T-score range	Pre-intervention n (%)	Post-intervention n (%)
Normal	≥ -1.0	40 (30.8)	65 (50.0)
Osteopenia	< -1.0 to > -2.5	55 (42.3)	50 (38.5)
Osteoporosis	≤ -2.5	35 (26.9)	15 (11.5)

C. Mean T-Score Comparison

TABLE III. REPORTED PRE- AND POST-INTERVENTION MEAN T-SCORES BY BMD CATEGORY.

BMD category	Pre-intervention mean (SD)	Post-intervention mean (SD)	Reported t	Reported p
Normal	0.5 (0.3)	1.5 (0.2)	14.50	<0.001
Osteopenia	-1.5 (0.4)	-1.0 (0.3)	5.75	<0.001
Osteoporosis	-3.0 (0.5)	-2.5 (0.4)	4.00	<0.001

The statistical values shown in Table III are reproduced from the supplied manuscript and require verification against the original statistical output before submission.

D. Factors Associated With BMD Score

TABLE IV. REPORTED ASSOCIATIONS BETWEEN PARTICIPANT CHARACTERISTICS AND BMD SCORE.

Variable	Mean T-score	SD	Reported χ^2	Reported p
Age	-0.84	0.96	4.12	0.13
Socioeconomic status	-0.63	0.88	8.56	0.03*
BMI	-0.54	0.83	10.34	0.02*
Physical activity level	-0.66	0.87	3.92	0.27
Dietary habits	-0.61	0.89	6.47	0.04*
Medical history	-0.75	0.91	7.89	0.02*
Menopausal status	-0.93	0.94	5.68	0.22
Religion	-0.88	0.91	2.74	0.43

* $p < 0.05$. The analytical scale and degrees of freedom for the reported chi-square tests should be verified against the original statistical output.

E. Figures

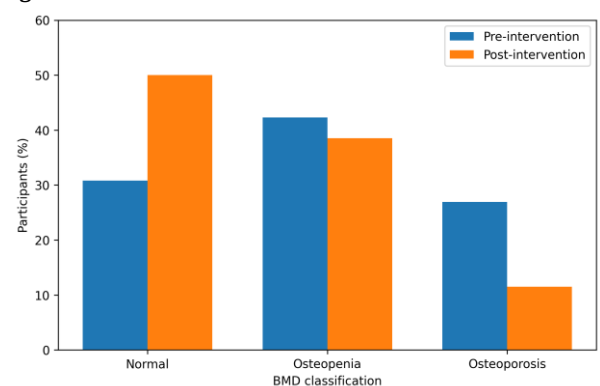


Figure 1. Distribution of BMD classification before and after the intervention.

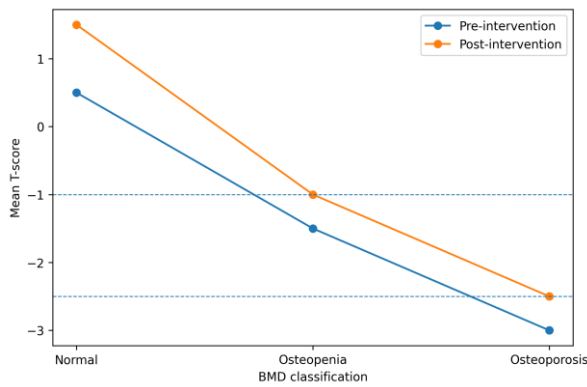


Figure 2. Reported mean T-scores by BMD category before and after the intervention.

IV. DISCUSSION

The study observed a favourable shift in the distribution of BMD categories after three months of the combined intervention. The proportion classified as normal increased from 30.8% to 50.0%, while the proportion classified as osteoporotic decreased from 26.9% to 11.5%. These findings are directionally consistent with evidence that exercise interventions can support BMD in postmenopausal women [5], [7].

The dietary component is also relevant because finger millet is a traditional cereal that can contribute minerals to the diet. Reviews have described its nutritional composition and functional properties, while experimental work has reported antioxidant and anti-inflammatory characteristics [8]–[10]. A previous study combining physical activity with a finger-millet-based food supplement also reported improvements in biochemical parameters and BMD, providing a rationale for the combined approach used in the present study [11].

The reported improvements in mean T-scores were statistically significant ($p < 0.001$). However, the magnitude and clinical meaning of these changes should be interpreted cautiously. BMD changes over a three-month period can be influenced by measurement precision, biological variability and other factors. In addition, the study did not include a control group, and therefore the observed changes cannot be attributed exclusively to finger millet supplementation, exercise or their combination. Socioeconomic status, BMI, dietary habits and medical history were reported to be associated with BMD score. The association with BMI is compatible with previous observational evidence linking body composition and bone density [4]. Dietary patterns and nutrient intake are also relevant to postmenopausal bone health [12].

The absence of statistically significant associations for age, physical activity level, menopausal status and religion should not be interpreted as evidence that these factors are unimportant

for bone health. In particular, the present analysis used broad categories and a relatively short intervention period, which may limit the ability to detect associations.

From a nutrition perspective, the study provides a practical example of incorporating a locally available traditional food into a community-oriented bone-health intervention. Nevertheless, the nutritional contribution of the finger millet product should be quantified in future work through nutrient analysis and clearly documented intake/adherence measures. Controlled trials with adequate follow-up are also needed to distinguish the effects of the food intervention from those of exercise and other concurrent factors.

V. STUDY LIMITATIONS

The principal limitation is the one-group pre-test/post-test design, which lacks a concurrent control group. Consequently, temporal changes cannot be attributed exclusively to the intervention. The intervention was also relatively short. The manuscript does not provide complete information on exercise frequency, session duration, progression, adherence, exact daily finger millet intake, or DXA measurement precision; these details should be added from the original study records before submission. The study also assessed BMD rather than fracture outcomes or longer-term skeletal outcomes.

VI. CONCLUSION

A three-month combined physical exercise and finger millet supplementation intervention was followed by an improvement in the distribution of BMD categories and reported T-scores among the 130 postmenopausal women studied. The findings support further investigation of food-based and physical-activity strategies for community bone-health promotion. Because the study lacked a control group and had a short follow-up period, the results should be considered preliminary and should be confirmed in controlled studies with clearly quantified dietary exposure, exercise dose, adherence monitoring and longer follow-up.

VII. ACKNOWLEDGMENT

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VIII. DECLARATIONS

Ethical Approval: Institutional Ethics Committee approval was obtained before commencement of the study (Approval No. IEC/C-P/63/2024).

Informed Consent: Written informed consent was obtained from all participants.

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Conflict of Interest: The source manuscript reports no conflicts of interest.

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