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Physical Activity, Muscle Mass, and Bone Mineral Density in Older Adults: A Cross-Sectional Study

A. Nurul Anisa Azis[1*], A. Rahmaniar Suciani Pujiningrum[2]

[1,2]Undergraduate Program in Physiotherapy, Faculty of Nursing, Universitas Hasanuddin, Makassar, Indonesia

*Corresponding author:
E-mail: anurulanisaazis@gmail.com
Phone: +62 897 9919 445

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Abstract

Introduction: The rising number of older adults each year poses significant public health challenges, particularly regarding musculoskeletal decline that reduces independence and quality of life. Muscle mass, bone mineral density (BMD), and physical activity are critical determinants of musculoskeletal health. This study aimed to examine the associations between physical activity, muscle mass, and BMD among older adults at Tamalanrea Primary Health Center, Makassar.

Methods: A cross-sectional study was conducted involving 133 purposively selected older adults. Physical activity was assessed using the standardized International Physical Activity Questionnaire (IPAQ). Muscle mass and BMD were measured using bioelectrical impedance analysis (BIA). Associations were tested using Somers' D, and correlation coefficients were calculated to determine the strength and direction of the relationships.

Results: Most participants demonstrated low to moderate levels of physical activity. Significant associations were observed between physical activity and muscle mass ($p < 0.001$, $r = –0.530$), as well as between physical activity and BMD ($p = 0.002$, $r = –0.263$). Negative correlations indicated that higher physical activity levels were linked with lower measured muscle mass and BMD, contrasting with previous findings that commonly reported positive associations.

Conclusion: Physical activity showed significant but inverse associations with muscle mass and BMD in older adults. Further studies are warranted to clarify underlying mechanisms and reconsider the role of physical activity in maintaining musculoskeletal health in aging populations.

Keywords

Aging, Older adults, Physical activity, Muscle mass, Bone density

Introduction

Older adults, defined as individuals aged 60 years and above, represent a rapidly growing population segment. The ageing population is a global phenomenon that cannot be avoided. According to the World Health Organization (WHO), the global number of older adults is projected to reach 2.1 billion by 2050, reflecting a significant upward trend.33 In Indonesia, data from the Central Bureau of Statistics (BPS) reported that the number of adults aged 80 years and older is expected to triple, reaching approximately 426 million between 2020 and 2050. In 2023, the proportion of older adults in Indonesia reached 11.75%, an increase from 10.48% in the previous year.[1]

A similar trend has been observed in South Sulawesi Province. Based on BPS data, the number of older adults in this province was approximately 0.92 million in 2020 (10.20%), which increased to 11.97% in 2023. By age distribution, 62.30% were classified as young-old, 28.65% as middle-old, and 9.05% as old-old. In Makassar City alone, the older adult population reached 141,894 in 2023, consisting of 52,560 aged 60–64 years, 36,825 aged 65–69 years, 23,698 aged 70–74 years, and 28,806 aged 75 years or above.[1] These statistics indicate a significant increase in the proportion of older adults in Makassar.

With advancing age, the musculoskeletal system undergoes physiological changes leading to functional decline, particularly the reduction of muscle mass. This decline results from a decreased number and size of muscle fibers and motor units.[2] Furthermore, age-related disruptions in denervation and reinnervation processes contribute to atrophy, especially in type II fibers, which are gradually replaced by adipose and connective tissue. Consequently, physical performance declines, and this process is closely associated with sarcopenia, a condition characterized by progressive loss of muscle mass and strength due to aging.[3]

In addition to muscle mass reduction, aging also leads to a decline in bone mineral density (BMD). With age, osteoblast activity decreases while osteoclast activity increases, resulting in greater bone resorption than formation.[4] Consequently, bone mass diminishes, increasing fragility and susceptibility to fractures, and leading to osteoporosis.[5] Osteoporosis is characterized by low bone mass, deterioration of bone microarchitecture, and increased fracture risk.[6]

Several factors influence the decline of muscle mass and BMD, including aging, hormonal changes, and physical activity. Elevated cortisol levels and reduced growth hormone associated with aging contribute to increased visceral fat, reduced muscle mass, and lower BMD.[7] In women, estrogen deficiency after menopause impairs osteoblast function, further reducing BMD.5 Low levels of physical activity among older adults have also been associated with decreased muscle mass, reduced bone quality, increased risk of osteoporosis, and higher susceptibility to fractures.[8]

Physical activity has been widely proposed as an effective strategy to slow musculoskeletal decline, as it improves muscle strength and stimulates bone formation.[7] However, Chattalia et al. reported that most older adults engage only in moderate levels of physical activity, which tends to decrease further with age due to diminished endurance and reduced participation in varied activities.[8] This reduction contributes to impaired coordination, muscle mass loss, decreased BMD, and joint changes, which collectively limit physical function.

Evidence suggests that physical activity offers multiple benefits, including cardiovascular protection, fall prevention, and improvements in muscle strength and bone density.[9] Studies by Buttan et al. and Lin et al. demonstrated positive associations between physical activity and BMD, particularly when weight-bearing and resistance exercises targeted the arms, legs, and pelvis.[10,11] Similarly, Suyanto et al. found that physically active older adults had greater muscle mass than their sedentary peers, underscoring the importance of activity in preserving muscle health.[12] However, Budiartha et al. reported no significant association between muscle mass reduction and functional status among older adults in Pedawa Village.[13]

Weight-bearing and resistance training are considered the most effective forms of activity for enhancing muscle mass and BMD. In contrast, heavy physical activity without proper structured training may provide limited skeletal benefits. Activities such as brisk walking, resistance training, circuit exercises, and calisthenics are particularly beneficial when performed regularly and progressively. For physically frail older adults, daily functional activities such as walking, proper lifting, and maintaining posture are also important for sustaining independence.[14]

Despite growing evidence, limited local data exist regarding the direct associations between physical activity, muscle mass, and BMD in older adults, particularly in the primary healthcare setting of Tamalanrea. Previous studies have often focused on single variables or different regions. Therefore, this study aimed to evaluate the relationships between physical activity, muscle mass, and BMD among older adults in Tamalanrea Primary Health Center, Makassar, to provide more locally relevant and comprehensive insights.

Methods

This study employed a descriptive correlational design with a cross-sectional approach, in which each variable was measured once at a specific point in time. The sample was selected using purposive sampling, and the sample size was determined using Slovin's formula with a 5% margin of error, yielding a total of 133 older adults from a population of 200. Data collection was conducted from January 16 to February 3, 2025, at Tamalanrea Primary Health Center, Makassar.

The study sample consisted of older adults who met predefined inclusion and exclusion criteria. The inclusion criteria were: age ≥60 years, absence of severe chronic diseases, engagement in physical activity at least three times per week for the past three months, and willingness to provide written informed consent. The exclusion criteria were: undergoing hormone therapy, having severe movement disorders, or having hearing impairments that limited participation. Participants were classified as drop-outs if they failed to complete all study procedures or were uncooperative.

Skeletal muscle mass was measured using Bioelectrical Impedance Analysis (BIA) with a Karada Scan Omron HBF-375 device. BIA is a rapid method for assessing body composition through tissue conductivity and is categorized according to the Asian Working Group for Sarcopenia (AWGS) recommendations into low, normal, and high.[13] The Karada Scan has demonstrated strong correlation with other reference methods, such as dual-energy X-ray absorptiometry (DEXA).[15]

Bone mineral density was assessed using BIA with the Xiaomi Mi Scale 2. This device provides a quick and practical assessment of bone health, with results categorized as standard or below standard.[16] Physical activity levels were assessed using the International Physical Activity Questionnaire (IPAQ). IPAQ measures physical activity based on the Metabolic Equivalent Task (MET) score over the past seven days and classifies it into light, moderate, and vigorous categories.[17]

For data analysis, univariate tests were applied to describe the frequency distribution of each variable. Bivariate analysis was performed to examine the significance and correlation coefficients between variables using Somers' D correlation test. This study received ethical approval from the Research Ethics Committee, Faculty of Nursing, Universitas Hasanuddin (Ethical Clearance No. 008/UN4.18.3/TP.01.02/2025).

Results

Data collection was conducted onsite at Tamalanrea Primary Health Center, Makassar, from 16 January to 3 February 2025, and included 133 older adults. No participants were excluded for incomplete data or withdrawal. Demographic and general characteristics are presented in Table 1. Most participants were aged 60–74 years (91.7%) and female (74.4%). More than half had a normal body mass index (BMI) (54.1%), and the most common occupation was homemaker (63.9%).

Table 1. Participant Characteristics (n = 133)

Characteristic	Category	n	%
Age	60–74 years (young-old)	122	91.7
	75–83 years (old)	11	8.3
Sex	Male	34	25.6
	Female	99	74.4
BMI	Underweight	9	6.8
	Normal	72	54.1
	Overweight	41	30.8
	Obese	11	8.3
Occupation	Laborer	6	4.5
	Homemaker	85	63.9
	Trader	17	12.8
	Retired	24	18.0
	Pedicab driver	1	0.7

Skeletal muscle mass distribution showed that 55.6% of participants were classified as normal, 27.8% as low, and 16.5% as high (Table 2).

Table 2. Distribution of Skeletal Muscle Mass

Muscle mass	n	%
Low	37	27.8
Normal	74	55.6
High	22	16.5
Total	133	100

Bone mineral density (BMD) distribution indicated that 65.4% of participants were below standard and 34.6% were within the standard category (Table 3).

Table 3. Distribution of Bone Mineral Density

Bone mineral density	n	%
Below standard	87	65.4
Standard	46	34.6
Total	133	100

Physical activity assessed using the IPAQ showed that 63.2% of participants had moderate activity, 21.1% light, and 15.8% vigorous (Table 4).

Table 4. Distribution of Physical Activity Level (IPAQ)

Physical activity level	n	%
Light	28	21.1
Moderate	84	63.2
Vigorous	21	15.8
Total	133	100

Cross-tabulation of physical activity with muscle mass showed that light activity was most frequent among participants with low muscle mass (17.3%), moderate activity among those with normal muscle mass (47.4%), and vigorous activity among those with high muscle mass (11.3%) (Table 5).

Table 5. Skeletal Muscle Mass by Physical Activity Level

Muscle mass	Light, n (%)	Moderate, n (%)	Vigorous, n (%)	Total, n (%)
Low	23 (17.3)	14 (10.5)	0 (0.0)	37 (27.8)
Normal	5 (3.8)	63 (47.4)	6 (4.5)	74 (55.6)
High	0 (0.0)	7 (5.3)	15 (11.3)	22 (16.5)
Total	28 (21.1)	84 (63.2)	21 (15.8)	133 (100)

The association between physical activity and muscle mass was statistically significant ($p < 0.001$), with a negative coefficient ($r = –0.530$), indicating an inverse relationship between the two variables (Table 6).

Table 6. Association Between Physical Activity and Skeletal Muscle Mass (Somers' D)

Variable pair	n	p-value	Coefficient (r)
Physical activity vs. muscle mass	133	<0.001	–0.530

Cross-tabulation of physical activity with BMD showed that light and moderate activity levels were most common among participants with below-standard BMD (20.3% and 45.1%, respectively), whereas vigorous activity was most frequent among those with standard BMD (15.8%) (Table 7).

Table 7. Bone Mineral Density by Physical Activity Level

BMD category	Light, n (%)	Moderate, n (%)	Vigorous, n (%)	Total, n (%)
Standard	1 (0.8)	24 (18.0)	21 (15.8)	46 (34.6)
Below standard	27 (20.3)	60 (45.1)	0 (0.0)	87 (65.4)
Total	28 (21.1)	84 (63.2)	21 (15.8)	133 (100)

The association between physical activity and BMD was significant but weak ($p = 0.002$; $r = –0.263$), indicating an inverse relationship overall (Table 8).

Table 8. Association Between Physical Activity and Bone Mineral Density (Somers' D)

Variable pair	n	p-value	Coefficient (r)
Physical activity vs. BMD	133	0.002	–0.263

Overall, these findings indicate statistically significant inverse associations between physical activity level and both skeletal muscle mass and BMD. Notably, descriptive cross-tabulations suggest that vigorous activity was more common among participants with high muscle mass and standard BMD; however, the overall correlation across categories remained negative, warranting cautious interpretation and further investigation of potential confounders.

Discussion

The findings of this study show that the majority of older adults in the Tamalanrea Primary Health Center, Makassar, were aged 60–74 years and predominantly female. Most respondents had normal muscle mass; however, more than half exhibited reduced bone mineral density, particularly among women. In terms of physical activity, a moderate level was most frequently observed, consisting mainly of light to moderate daily activities such as household chores, light exercise, or walking. These findings are consistent with data from the 2020 Statistics Bureau, which reported that in South Sulawesi, the 60–69-year age group contributed the largest proportion of the older population, accounting for approximately 27,100 individuals. Furthermore, the results align with Suhada et al., who found that most older adults demonstrated moderate levels of physical activity, representing 55% of respondents.[18]

Association Between Physical Activity and Muscle Mass

This study demonstrated a significant association between physical activity and muscle mass among older adults at the Tamalanrea Primary Health Center, with p = 0.000 (<0.05) and a correlation coefficient r = -0.530. The negative correlation indicates an inverse relationship, suggesting that higher levels of physical activity were associated with lower muscle mass.

This finding supports Suhada et al., who reported a negative correlation between physical activity and muscle mass, whereby greater physical activity was linked to reduced muscle mass and strength.[18] Similarly, Rostron et al. highlighted the relationship between physical activity levels and lower limb muscle mass and strength.[19] Conversely, Budiartha et al. reported no significant association between muscle mass decline and functional status among older adults in Pedawa Village.[13]

In this study, most participants engaged in moderate physical activity, which primarily involved household chores rather than structured or routine exercise. Moderate and light activity was commonly observed among housewives, who typically performed light household tasks and light exercises such as walking for 10–30 minutes or morning calisthenics. Such limited activity does not provide sufficient stimulus to maintain or enhance muscle mass, thereby accelerating muscle degeneration and increasing the risk of sarcopenia.[20]

In contrast, older adults who engaged in vigorous physical activity tended to maintain better muscle mass. In this study, vigorous activities included weightlifting, gardening, and structured exercise. Vigorous physical activity imposes significant mechanical load on muscles, which is crucial for preserving or increasing muscle mass and reducing the risk of age-related sarcopenia.[21]

Loss of muscle mass is primarily due to progressive muscle atrophy, a reduction in type II muscle fibers, motor neuron loss, and fat infiltration. The decline in muscle mass and strength is multifactorial, influenced by lifestyle, neuromuscular degeneration, and hormonal changes.[22] With aging, failure of cycles of denervation and reinnervation accelerates type II fiber atrophy, leading to gradual reduction in size and volume, often replaced by fat and connective tissue.[23]

This is supported by Yerrakalva et al., who found that physical behavior change is strongly associated with muscle mass. Older adults who engaged in daily walking for 30 minutes gained greater muscle mass benefits compared with those who performed only 10 minutes of activity.[24] Structured activities such as strength training and weightlifting were also shown to be more effective in increasing muscle mass and strength.[24] Similarly, Suyanto et al. demonstrated differences in muscle mass between physically active and inactive older adults.[12]

Besides physical activity, muscle mass in older adults is influenced by hormonal changes (decline in testosterone and estrogen) and inadequate protein intake. Protein is essential for muscle synthesis, and insufficient intake accelerates muscle loss, particularly when unaccompanied by sufficient physical activity. Wihelmina et al. emphasized that regular exercise combined with protein-rich nutrition provides the best outcomes in improving muscle mass.[25]

Therefore, older adults should be encouraged to engage in structured exercise, including strength training at least twice per week, along with cardiovascular exercise such as brisk walking or cycling for a minimum of 150 minutes per week. Adequate intake of protein, vitamins, and minerals should also be prioritized to maintain muscle mass and prevent sarcopenia.

Association Between Physical Activity and Bone Mineral Density

Statistical analysis revealed a significant association between physical activity and bone mineral density among older adults in the Tamalanrea Primary Health Center. Somers' D correlation yielded a p-value of 0.002 (<0.05) with r = -0.263, indicating a negative relationship, whereby higher levels of physical activity were associated with lower bone mineral density. This suggests that moderate physical activity may not provide sufficient benefit for improving bone density, which can also be influenced by other factors such as age, sex, type of activity, genetics, diet, and occupation.

These results are consistent with Buttan et al., who found that higher levels of physical activity were associated with improved bone mineral density.[10] However, Akai et al. reported no significant association, concluding that increased

bone density in older Japanese adults was not attributed to physical activity, as it was not considered a major determinant.[26]

The inverse association found in this study may be due to the predominance of moderate activity levels among participants, which largely consisted of light daily activities such as household chores, casual walking, or light calisthenics. While beneficial for mobility and general fitness, such activities do not provide adequate mechanical loading necessary to stimulate bone remodeling and enhance density. Without weight-bearing or vigorous activity, older adults may fail to maintain or improve bone mineral density.

The type of physical activity is critical in influencing bone health. Bella et al. demonstrated that anaerobic activities such as running, weightlifting, and jumping were particularly effective in improving bone mineral density.[27] Rondanelli et al. also emphasized that higher levels of physical activity promote bone remodeling through mechanical loading, stimulating osteocytes and enhancing osteoblast activity, thereby increasing bone mass.[28] Conversely, insufficient activity reduces osteoblast stimulation, impairing calcium phosphate deposition in bone and contributing to bone mass loss.[28] Thus, structured, moderate-to-vigorous activities such as brisk walking, cycling, or strength training, performed regularly and progressively, are highly recommended for older adults.

Other factors also play a significant role, including hormonal and nutritional status. Women experience a more rapid decline in bone mineral density than men due to postmenopausal estrogen loss. Ning et al. reported that estrogen deficiency accounts for up to 90% of bone resorption, making women more susceptible to osteoporosis.[29] Estrogen is critical in maintaining bone mineral density, particularly after menopause.[29] In addition, reduced growth hormone (GH) and insulin-like growth factor-1 (IGF-1), along with elevated cortisol, further contribute to bone density loss in older adults.[3]

Nutritional intake, especially calcium and vitamin D, is also essential for bone health.[30] While physical activity is beneficial, optimal bone mineral density requires a combination of appropriate exercise, adequate nutrition, and overall health maintenance.

This study has several limitations. First, the cross-sectional design precludes the ability to determine causal relationships. Second, nutritional factors were not assessed, which may have influenced the findings. Third, the study was limited to older adults in one region, the Tamalanrea Primary Health Center, Makassar, thus the results may not be generalizable to other populations. Future research should consider additional variables such as type of physical activity, dietary intake, and hormonal status.

In conclusion, this study highlights the critical role of physical activity in maintaining muscle and bone health among older adults. Vigorous physical activity was associated with greater muscle mass and bone mineral density, whereas light to moderate activity appeared insufficient to prevent declines. Therefore, older adults are strongly encouraged to increase their level of structured physical activity and maintain adequate nutritional intake to promote musculoskeletal health and improve quality of life.

Conclusion

The results of this study demonstrate a significant association between physical activity and both muscle mass and bone mineral density among older adults at the Tamalanrea Primary Health Center, Makassar, with a negative correlation observed. This indicates that higher levels of physical activity were accompanied by a decline in muscle mass and bone mineral density. Such findings may be explained by the predominance of light to moderate activities, which fail to provide sufficient anabolic stimulus to maintain or improve muscle mass and bone mineral density. Additional factors such as age, sex, hormonal status, and nutrition likely contributed to these outcomes.

Therefore, it is recommended that physical activity programs for older adults emphasize improving both the quality and intensity of exercise. Structured activities such as light-to-moderate resistance training, endurance exercises, and functional movements should be prioritized, as they have been shown to effectively stimulate increases in muscle mass and bone mineral density. This approach is essential to preserve musculoskeletal health and reduce the risk of mobility impairments in older adults.

Author Contribution

A.N.A.A. and A.R.S.P. contributed equally to the conception, design, data collection, analysis, and interpretation of the study. Both authors drafted and critically revised the manuscript, approved the final version, and agree to be accountable for all aspects of the work.

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Conflict of Interest Statement

The authors declare no conflicts of interest related to this work.

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Ethics Statement

This study was approved by the Research Ethics Committee of the Faculty of Nursing, Universitas Hasanuddin (Ethical Clearance No. 008/UN4.18.3/TP.01.02/2025). Written informed consent was obtained from all participants prior to data collection.

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