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Physical activity and bone mineral density in Greek women: an observational study

Sideri Konstantina[1], Demetriou Andriana[1], Stasi Sophia[1], Stamou Magdalini[1], Papathanasiou Georgios[1]
[1] Laboratory of Neuromuscular and Cardiovascular Study of Motion (LANECASM), Physiotherapy Department, University of West Attica

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Note: Mrs. Demetriou Andriana and Mrs. Sideri Konstantina participated equally in the research procedures and in the writing of the article.

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ABSTRACT

Purpose: This observational study aimed to investigate the correlation between physical activity (PA) and bone mineral density (BMD) in Greek women.

Materials - Methods: 46 women (aged >45 years) participated and grouped according to their BMD into three groups: Group A (normal BMD), Group B (osteopenia), and Group C (osteoporosis). The evaluation of PA and lower limb endurance (LLE) was carried out through the Greek version of the International Physical Activity Questionnaire-short version (IPAQ-Gr), and 30 seconds sit-to-stand (30STS) test, respectively. Multivariate analysis of variance (MANOVA) and Post-Hoc comparison (Tukey's test) were used for the statistical analysis. The correlations between BMD and the variables: age, height, weight, body mass index, 30STS, and IPAQ-Gr were calculated using the Pearson's *r* correlation coefficient. Statistical significance was set at $p<0.05$.

Results: The results showed that PA, as expressed with the IPAQ-Gr, has a weak and positive correlation to BMD (r=.209, p=.163). The best correlation, with a statistically significant difference, was weak and negative and found to be between the age and BMD (r=-.287, p=.05). Post-Hoc comparison demonstrated statistically significant differences in the 30STS between Group A (normal BMD) and Group C (osteoporosis) (p=.01).

Conclusions: As expected, BMD was found to be age-related, while statistically significant was the difference between LLE of women with normal BMD in relation to osteoporotic women. PA seemed to have a positive effect on BMD, although no statistically significant difference was found. However, further research needs to be conducted with larger sample size to investigate the relationship between physical activity and BMD.

Key words: physical activity, bone mineral density, quantitative ultrasound, Greek version of international physical activity questionnaire-short version, 30 seconds sit-to-stand test

Introduction

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that requires energy expenditure (Dasso, 2019). Regular exercise has been shown to contribute to the prevention of hypertension, the maintenance of a normal body weight and, in general, to the improvement of the person's quality of life (Dasso, 2019; Pinheiro et al, 2020).

However, PA can be affected by a number of factors, the most important being the increase in age. Older adults appear to have lower participation rates in Physical activity, approximately 40-80% less than young people (Suryadinata et al, 2020; Westerterp, 2018). Statistics indicate that, in the United States of America, only 16% of adults aged 65 years or older, follow the guidelines for exercise (aerobics or/and empowerment (Cauley & Giangregorio 2020). In Europe, less than a third of adults perform moderate intensity exercise (at least 150 minutes) or vigorous intensity exercise (at least 75 minutes) per week, as it is clearly recommended by the World Health Organization (Cauley & Giangregorio 2020; Warburton & Bredin 2017).

In parallel, osteoporosis is defined as a systemic skeletal disease, characterized by low BMD and microarchitectural deterioration of bone tissue, resulting in reduced mechanical strength of the bones and an increased risk of fractures. (Compston et al, 2019). Epidemiological studies report that osteoporosis is a silent chronic disease of global scope. Specifically, in the United States between 2005 and 2010, it was estimated that 10.2 million older adults suffered from osteoporosis while 43.4 million older adults had osteopenia. (Cooper & Ferrari 2019). In 2019 in Europe it was estimated that 25.5 million women and 6.5 million men suffered from osteoporosis (Willers et al, 2022). Regarding the epidemiological data of osteoporosis among the Greek population, it is estimated that in 2019, approximately 684,000 people were affected, of which 80% were women (Willers et al, 2022).

PA can stimulate bone growth and maintain or even improve bone mass through the mechanical effects of gravity, and from concentric muscle contraction (Muir et al, 2013; Pinheiro et al, 2020; Tong et al, 2019). This adaption of osteocyte metabolism results in long-term changes in the macro- and micro architecture of bones, their shape and structure (Lombardi et al, 2019). Through this mechanism, PA promotes the formation of osteitis tissue, which could effectively prevent and treat osteoporosis, without the impact of the side effects of anti-osteoporotic medication, with low economic cost and high personalization (Tong et al, 2019; Troy et al, 2018).

In recent years, due to longer life expectancy, the rapid increase in the population of older adults has brought about a number of health problems that need intervention, including osteoporosis (Tong et al, 2019). Adequate PA seems to have an effect on both the prevention and treatment of osteoporosis, delaying the loss of BMD and muscle mass. The association of PA with osteoporosis is still a current field of research (Tolomio et al, 2008).

The purpose of this observational study is to investigate the association of PA with BMD in Greek women. The results may provide important evidence which through this correlation, a need may arise to create programs to inform and give targeted guidelines for the prevention of osteoporosis. Furthermore, a wider awareness of the findings in the Greek population would facilitate objective comparisons between studies of different ethnic origins and could contribute to future meta-analyses.

Material- Methods

Study design

The present observational study was carried out through the voluntary action of the OSTEOSAF group in the works of the “Petalouda" Skeletal Health Association and in which the authors of this article participated. The research protocol of the study was approved by the Research Ethics and Ethics Committee of the University of West Attica (No. Prot.: 19725-28/02/2023).

Population

Women over 45 years of age participated in the research. The participants were recruited by the “Petalouda" Skeletal Health Association. The main inclusion criterion of the study was the measurement of the BMD of the participants. People who faced serious neurological problems, dementia, had balance disorders and in general any condition likely to affect their performance in the objective tests were excluded from the research. On the day of the measurements, the subjects who accepted their participation in the study gave their written consent in accordance with the principles of the Declaration of Helsinki and its subsequent amendments (World Medical Association- Declaration of Helsinki, 2013) and their demographical and clinical characteristics were recorded.

Variables/ Evaluation Procedures

In the present study, measurement of BMD, evaluation of PA and lower limb endurance (LLE) were carried out.

The measurement of BMD was carried out with the method of calcaneal quantitative ultrasound (QUS) (Chin & Ima-Nirwana, 2013; Hans et al, 2022). The Greek version of the self-reported International Physical Activity Questionnaire- short version (IPAQ-Gr) was used to evaluate the PA of the participants (Papathanasiou et al, 2009). The lower limb endurance (LLE) was measured through the 30 seconds sit-to stand (30STS) test (Gürses et al, 2020; Stasi et al, 2021; Yee et al, 2021). Details of the measurements and evaluation procedures are described in the Appendix.

The participants were divided into three groups according to their BMD. Group A consist of women whose BMD was within the normal range (T-score >-1SD). Women whose BMD was on the borderline of osteopenia (T-score <-1 to >-2.5 SD) and women who had osteoporosis (T-score <-2.5 SD) were included in group B and group C, respectively. The examiner did not know to which of these groups each participant belonged to.

Statistical Analysis

Statistical analysis was performed using IBM® SPSS® software package version 28 (IBM Corporation, Somers, NY, USA). Tests were two-tailed and statistical significance was set at $p<0.05$.

Data were expressed for continuous variables as mean±standard deviation (SD). The Kolmogorov-Smirnov test examined the normal distribution of the parameters.

The effect of the independent variables (age, height, weight, BMI, 30STS, IPAQ-Gr - Vigorous, IPAQ-Gr - Moderate, IPAQ-Gr - Walking, IPAQ-Gr - Total) on the dependent BMD was examined using the multivariate analysis model (MANOVA), and for pairwise comparisons Tukey's HSD test was used. Furthermore, a multinomial logistic regression was performed using the fit model method to assess the effect of the independent variables on the variable under consideration (BMD)

Correlations between the BMD and the continuous response variables were calculated using the Pearson's correlation coefficient (r). Pearson's correlation coefficient (r) is the most common way to calculate a linear correlation. Specifically, it is a number between -1 and 1 that measures how strong the correlation is between two variables, but also shows its direction (Turney,2022).

Results

Study population

Initially, 60 individuals were selected, of which 14 were excluded. Specifically, four were male, three had not undergone BMD measurement, and seven had comorbid neurological conditions. Finally, 46 women were included in the survey. Eleven women had normal BMD and were assigned to group A; 20 women had osteopenia and were included in group B, and 15 were osteoporotic and formed group C. The demographic and clinical characteristics are presented in Table 1.

Table 1. Demographic and Clinical Characteristics of Participants

	Group A (N=11)	Group B (N=20)	Group C (N=15)	Total sample size (N=46)
Age (years)	67.5(±8.4)	66.8(±6.4)	72.5(±8.1)	68.8(±7.7)
Height (cm)	163.9(±6.5)	160.2(±5.5)	159.5(±8.1)	160.8(±6.8)
Weight (Kg)	76.8(±11.5)	67.9(±13.3)	67.4(±11.2)	69.8(±12.6)
Body Mass Index (Kg/m^2)	28.6(±3.9)	26.3(±4.4)	26.4(±3.4)	26.9(±4.0)
Bone Mineral Density (T-score)	-0.62(±-0.38)	-1.9(±-0.26)	-3.1(±0.75)	-5.62(±1.39)
30sec sit-to-stand (repetitions)	12.4(±1.4)	10.8(±3.0)	9.2(±2.6)	10.7(±2.8)
IPAQ-Gr - Vigorous ($MET.min.wk^{-1}$)	174.5(±443.7)	382.0(±572.2)	320.0(±123.9)	218.2(±459.0)
IPAQ-Gr - Moderate ($MET.min.wk^{-1}$)	932.7(±1428.2)	754.8(±874.6)	568.0(±696.1)	736.4(±972.6)
IPAQ-Gr - Walking ($MET.min.wk^{-1}$)	652.5(±437.5)	842.3(±578.1)	755.7(±677.8)	768.6(±576.5)
IPAQ-Gr - Total ($MET.min.wk^{-1}$)	1759.7(±1238.2)	1979.1(±1494.5)	1355.7(±792.9)	1723.7(±1246.5)

Table 1. Demographic and Clinical Characteristics of Participants

	Group A (N=11)	Group B (N=20)	Group C (N=15)	Total sample size (N=46)

Group A: Normal Bone Mineral Density, Group B: Osteopenia, Group C: Osteoporosis

IPAQ-Gr: Greek version of International Physical Activity Questionnaire-short version

Measurements

The mean (±SD) of the measurements of the BMD (T-score), 30STS test (repetitions), and IPAQ-Gr (MET.min.wk-1) of the three groups are presented in Table 1. Post-hoc comparison using Tukey's test revealed statistically significant differences in mean 30STS repetitions between Group A and Group C (Mean difference, p=0.01). The comparisons of each variable between the three groups are presented in Table 2.

Table 2. Multiple comparisons (pairwise) between study's groups

Variables	Pairs of Groups	Mean Difference	Standard Deviation	Significance (p-value)
	Group A - Group B	.74	2.8	.96
Age (years)	Group A - Group C	- 4.7	2.9	.22
	Group B - Group C	- 5.7	2.5	.07
	Group A - Group B	3.6	2.5	.32
Height (cm)	Group A - Group C	4.3	2.6	.24
	Group B - Group C	.71	2.3	.94
	Group A - Group B	8.9	4.6	.14
Weight (Kg)	Group A - Group C	9.4	4.8	.14
	Group B - Group C	.50	4.2	.992
	Group A - Group B	2.2	1.5	.30
BMI (Kg/m^2)	Group A - Group C	2.1	1.5	.36
	Group B - Group C	- .07	1.3	.99
	Group A - Group B	1.6	.98	.24
30sec sit-to-stand (repetitions)	**Group A - Group C**	**3.1**	**1.0**	**.01**
	Group B - Group C	1.5	.89	.193
	Group A - Group B	-207.4	165.9	.84
IPAQ-Gr - Vigorous ($MET.min.wk^{-1}$)	Group A - Group C	142.5	175.5	.69
	Group B - Group C	350.0	151.0	.43
	Group A - Group B	179.9	369.7	.88
IPAQ-Gr - Moderate ($MET.min.wk^{-1}$)	Group A - Group C	364.7	390.9	.62
	Group B - Group C	186.8	336.4	.88
	Group A - Group B	- 189.8	219.4	.66

Table 2. Multiple comparisons (pairwise) between study's groups

Variables	Pairs of Groups	Mean Difference	Standard Deviation	Significance (p-value)
IPAQ-Gr - Walking (MET.min.wk^{-1})	Group A - Group C	-103.2	232.0	.89
	Group B - Group C	350.0	151.0	.64
IPAQ-Gr - Total (MET.min.wk^{-1})	Group A - Group B	- 219.3	467.0	.88
	Group A - Group C	404.0	493.9	.69
	Group B - Group C	623.4	425.0	.31

Group A*:* Normal Bone Mineral Density, Group B: Osteopenia, Ομάδα C: Osteoporosis
IPAQ-Gr: Greek Version of International Physical Activity Questionnaire–short version
*Note.*Tukey HSD, Mean Difference sig. 5%

The multivariate logistic regression between BMD and the variables (age, height, weight, BMI, IPAQ-Gr - Vigorous Physical Activity, IPAQ-Gr - Moderate Physical Activity, IPAQ-Gr - Walking and IPAQ-Gr - Total) did not show a statistically significant difference (p=0.91), so the variables mentioned above did not affect the participants' BMD.

Finally, pearson's correlation coefficient (r) was calculated between BMD and each independent variable. The best correlation, with a statistically significant difference, was weak and negative and was found to be between age and BMD (r= -.287, p=.05). Characterized as weak, positive, and without statistical significance were the correlations between BMD and the variables: height, weight, BMI, 30STS, IPAQ-Gr (Table 3).

Table 3. Correlations between Variables

	Variables	**Correlation Coefficient Pearson's *r***	**Significance (*p*-value)**
Bone Mineral Density	**Age (years)**	**-.287**	**.05**
	Height (cm)	.103	.496
	Weight (Kg)	.188	.210
	Body Mass Index (Kg/m^2)	.168	.266
	30 sec sit-to-stand test (repetitions)	.266	.074
	IPAQ-Gr - Vigorous (MET.min.wk^{-1})	.178	.236
	IPAQ-Gr - Moderate (MET.min.wk^{-1})	.160	.288

Table 3. Correlations between Variables

Variables		Correlation Coefficient Pearson's *r*	Significance (*p*-value)
	IPAQ-Gr - Walking (MET.min.wk^{-1})	.040	.792
	IPAQ-Gr - Total (MET.min.wk^{-1})	.209	.163

IPAQ-Gr: Greek Version of International Physical Activity Questionnaire–short version

Discussion

This research examined the correlation between PA and BMD in Greek women. The results showed that the BMD has a weak and positive correlation with the 30STS test and PA, as expressed by the self-completion questionnaire IPAQ-Gr.

The best and most statistically significant correlation was between age and BMD. More specifically, this correlation was characterized as negative, meaning BMD decreases with increasing age. This finding is consistent with the results of other studies, where it is reported that with increasing age, there is an increase in the proportion of women with osteoporosis and, thus, a decrease in BMD. According to a systematic review, it is reported that the rate of loss of BMD each year increases progressively with age, by 0.6 % and 1.1 % for the age groups 60-69 and 70-79 years, respectively (Gómez-Cabello et al., 2012). In the United States, it has been found that the percentage of women with osteoporosis in the age group 50-64 years was 13.1%, while in the age group of 65 and older, this percentage rose to 27.1% (Sarafrazi, 2021). The percentage mentioned above is in line with the percentage found in the present study, where 32.6% of the participants had osteoporosis. It has also been reported that in Austria, in the age group 70-74 years, 33% of women have osteoporosis. (Boschitsch et al, 2017). The fact that osteoporosis is age-dependent is confirmed by international literature, and indeed, it can be seen from the present research work that in Greece, similar rates of osteoporosis are observed as those in Europe and America (Sarafrazi, 2021; Boschitsch et al, 2017).

The sample of women in this study had a BMI exceeding the upper limit of normal (24.9 kg/m²), classifying them as overweight. Although no statistically significant difference was found between the groups, it was observed that the BMI of group A was higher by about 7.8% compared to groups B and C. This finding may be justified by the fact that there is a correlation between high BMI and better BMD. In particular, it has been found that there is a positive correlation between BMI and BMD in older adults, and specifically, a one-point increase in BMI was associated with a 0.0082 g/cm2 increase in total BMD (Lloyd et al., 2014). These findings are supported by other studies reporting that lower BMI is a risk factor for the development of lower BMD and also that the prevalence of osteoporosis was lower in obese women compared to non-obese women (Fawzy et al, 2011; Hssan et al, 2020).

In the 30STS test, a statistically significant difference was observed between groups A and C, demonstrating that the reduction in BMD is associated with LLE, as expressed by the number of the 30STS test repetitions. However, the correlation between the two variables was found to be weak and positive. During the literature search, studies were found that studied women of a similar age group to those in the present study. Specifically, it has been found that women in the age range 65-69 years, without reporting their T-score, performed on the 30STS test an average of 13.5 (±SD=3.5) repetitions (Rikli & Jones, 1999). It has also been reported that women over 60, whose BMD status was not reported, performed an average of 12.7 (±SD=3.6) repetitions (Jones et al, 1999). The number of repetitions of these studies is consistent with the number of repetitions of the 30STS performed by the women in group A of the present study. It should be noted that, during the literature review, no study was found that directly correlated 30STS test repetitions with T-score.

No studies were found examining physical activity in women with osteoporosis using the IPAQ-Gr during the literature review. Thus, a comparison of our results cannot be made. The measurement of PA using the IPAQ-Gr did not show a statistically significant difference between the groups. However, it can be seen that group B performed more vigorous PA and walking compared to the other groups, while group A performed more moderate PA. The finding that, osteopenic women were more active than the others may be due to their intention to remain active, knowing that their BMD has started to decrease.

Participants in group C were older than the other groups and performed less PA (more walking). This result may be due to the older age of group C participants, as it has been reported that after 60 years, increasing age results in a decrease in PA, which can reach 40-80% at older ages (Gómez-Cabello et al, 2012; Westerterp, 2018; Suryadinata et al, 2020). Also, studies report that after 52 years, vigorous and moderate PA gradually decreases more, as observed in group C participants (Ayabe et al, 2009).

This research study has advantages and disadvantages. In terms of advantages, this study had a homogeneous sample, as no statistically significant differences were observed between the characteristics of the three groups, except for age. Another advantage is that the recording of PA was subjective as the participants conducted it and reflected their perception of their level of PA. When conducting the 30STS objective test, the assessors did not know which of the three groups the participants belonged to, ensuring the measurements' objectivity. Finally, adequate statistical analysis gives the present study another advantage. However, the study has several disadvantages, including the relatively small sample size, which may be the reason that no statistically significant difference was found. Another disadvantage is the non-recording of any coexisting musculoskeletal conditions, which may have influenced the participants' PA levels. Also, no follow-up measurement was performed to investigate any difference in the levels of PA and BMD over time.

Conclusion

This study investigated the correlation between PA and BMD in Greek women. The results showed a weak but statistically significant correlation between age and BMD and a significant difference in the 30STS test between women with normal BMD and osteoporotic women. As assessed by the IPAQ-Gr questionnaire, PA appeared to have a positive effect on BMD, although no statistically significant difference was found. However, further research is recommended with more participants to ascertain the correlations between BMD and PA as expressed by the IPAQ-Gr. Furthermore, a broader awareness of the findings in the Greek population would facilitate objective comparisons.

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Appendix. Evaluation Tools and Procedures

Quantitative Ultrasound	Bone density was measured using Quantitative Ultrasound (QUS) which offers portable and accurate technology to measure bone density in the heel. Quantitative ultrasound does not use ionizing radiation and is less expensive than the Dual-Energy X-Ray Absorptiometry (DEXA) (Chin & Ima-Nirwana, 2013; Hans et al., 2022). The Achilles InSight machine from General Electric was used to measure bone density in the heel bone of the participants in this study.
Greek version of the International Physical Activity Questionnaire-short version	The self-completed Greek version of the International Physical Activity Questionnaire-short version (IPAQ-Gr) is a scale to assess a person's physical activity (PA) in the last week. It consists of 7 questions, of which, the first 6 questions relate to the number of days (frequency) and the number of minutes per day (duration) of participation in PA. Specifically, the first two questions relate to vigorous PA, the 3rd and 4th to moderate PA, while the 5th and 6th include the recording of walking for more than 10 minutes. Finally, the 7th question records the amount of time the person spends sitting, an average normal day in the previous week. The scale scores are initially calculated separately for each category, excluding question 7, which is not included. For the calculation, the frequency and duration of each category is multiplied together with a value of METs set for each category: 8.0 for vigorous PA, 4.0 for moderate PA and 3.3 for walking. Specifically, the score for vigorous PA is equal to 8*(days of vigorous PA) *(minutes of vigorous PA during the day), the score for moderate PA is equal to 4.0*(days of moderate PA)*(minutes of moderate PA during the day), and finally, the score for walking is equal to 3.3*(days of walking)*(minutes of walking during the day). Then, to calculate the total score, the three categories are added together, (Total PA score = Vigorous PA score + Moderate PA score + Walking PA score), and depending on the result, the person's PA is classified as low, moderate or high. Interpreting the scores, when the individual has a total score <600MET.min.wk1 then they are considered to be performing generally low PA, whereas when the vigorous PA is ≥480 MET.min.wk-1 or the total score is ≥600 MET.min. wk-1, the individual is considered to be performing moderate PA. Finally, when the vigorous PA score is ≥1500MET.min.wk-1 or the total score ≥3000 MET.min.wk-1, the individual is considered to be performing high PA (Papathanasiou et al., 2009).
30 seconds Sit-to-stand Test	The 30STS is a test to assess strength and functionality, as it appears to be influenced by lower limb strength, balance and endurance (Gürses et al, 2020; Yee et al, 2021). The test is performed as follows: the participant sits in the middle of a chair, approximately 43 cm without arms, which is fixed to the wall for safety reasons, with arms ideally crossed at chest height, and back in a straight posture. Participants' feet must be on the floor. The aim of the test is for the participant to stand up from the chair, with knees fully extended, and to sit back down in the chair as many times as possible within the 30-second period. Before the start, the test is explained and demonstrated and then the participant is given the opportunity to perform 1-2 test lifts. The outcome of this test is the number of repetitions performed by the subject (Gürses et al, 2020; Stasi et al, 2021; Yee et al, 2021). In cases where the risers are performed incorrectly, they are not considered in the total score, and in the last second, the riser, if performed up to the standing position, is counted in the total number of repetitions (Jones et al., 1999)