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Effect of Lifetime Occupational Physical Activity on Indices of Bone Mineral Status in Healthy Postmenopausal Women

J. Damilakis,[1] K. Perisinakis,[1] G. Kontakis,[2] E. Vagios,[3] N. Gourtsoyiannis[1]

[1]University of Crete, Faculty of Medicine, P.O. Box 1393, 711 10 Iraklion, Crete, Greece
[2]University Hospital of Iraklion, P.O. Box 1393, 711 10 Iraklion, Crete, Greece
[3]Pagritia Igia Diagnostic Center, Iraklion, Crete, Greece

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Abstract. The purpose of this study was to examine the effect of lifetime physical activity of farmers on skeletal status. Seventy-one healthy, postmenopausal women (mean age 52.3 ± 5.9 years, range 42–61 years) who worked professionally on farms were compared with 78 matched controls (mean age 51.8 ± 5.5 years, range 42–61 years). Broadband ultrasound attenuation (BUA) and speed of sound (SOS) at the os calcis were measured using an ultrasound transmission imaging system. Bone mineral density (BMD) of the lumbar spine and femoral neck were measured by dual-energy X-ray absorptiometry (DXA). Differences in BUA, SOS, and BMD between farmers and controls were expressed relative to standard deviation (SD) of the farmers. Farmers had significantly higher density values than controls (difference = 1.3 SD in the spine and 1.5 SD in the femoral neck, $P < 0.0001$ for both comparisons). Ultrasound values were significantly higher in the farmers compared with the controls in calcaneus (difference = 1.1 SD for BUA and 0.7 SD for SOS, $P < 0.0001$ for both comparisons). The difference of spine BMD, femoral neck BMD, BUA, and SOS between farmers and controls, as judged by comparison of the slopes of the regression lines, was unchanged with age and years since menopause. These results suggest that lifetime physical activity has a positive effect on bone status of postmenopausal farmers.

Key words: Quantitative ultrasound — Bone mass measurements — Physical activity — Osteoporosis — Postmenopausal women.

Physical activity appears to play an important role in the development and maintenance of bone mineral density (BMD). Various studies have demonstrated the beneficial effects of physical activity on growing bone [1–4]. Numerous others have reported higher bone densities in athletes compared with the normal population [5–8]. Regular exercise could be a valuable way to retard bone loss in postmenopausal women [9–15]. However, the impact of lifetime physical activity on bone status has not been well established. Hoshino et al. [16] and Hu et al. [17] demonstrated a positive effect of long-term activity on bone. However, Greendale et al. [18] found no association between current or lifetime exercise and BMD at radius, wrist, or spine. Moreover, habitual daily walking and stair climbing by healthy premenopausal women appeared to be insufficient exercise stimulus to increase BMD above values found in a group of sedentary office workers [19].

In most studies on the influence of physical activity on skeletal status, bone measurements have been taken with BMD devices (i.e., DXA and computed tomography (CT) scanners). Ultrasound measurements can provide useful information not only about density but complementary information about bone structure [20–22]. Nevertheless, there is limited reported experience regarding the effects of physical activity on ultrasound measurements of the calcaneus. Jones et al. [23] reported that in formerly sedentary women, a modest program of brisk walking can provoke an increase in broadband ultrasonic attenuation (BUA). Hoshino et al., [16] using quantitative ultrasound measurements, demonstrated that caddies have higher ultrasound values of the os calcis and lower bone resorption after menopause compared with controls. Recently, Brooke-Wavell et al. [24] showed that the change in BUA observed in subjects following a 12-month program of brisk walking differed from that in control subjects in the calcaneus.

In the present study we examined the effect of lifetime occupational physical activity on skeletal status in healthy postmenopausal women using DXA and two ultrasonic indices of bone status: BUA and speed of sound (SOS).

Materials and Methods

The present study is based on 71 healthy Caucasian women aged 42–61 years (mean 52.3 ± 5.9) who were professional farm workers. All women were interviewed using a structured medical questionnaire for medical history and occupational background. Questions concerning daily physical activity included the average time spent working in the fields, the type of daily work, and the intensity of work. Classification of vigorous physical activity is much more reliable than classification of moderate activity, therefore, only women who worked full time since the age of 18 or earlier, undertaking heavy labor manual work, were considered for the study. Only 2 (3%) farmers smoked, from 10 to 20 cigarettes daily. Using information from the questionnaires, women with a history of hypoparathyroidism, hyperparathyroidism, or any other metabolic bone disorder were excluded.

The control group comprised 78 office workers or housewives aged 42–61 years (mean 51.8 ± 5.5) living in the same region as our study population. The women of this group were a subset of the participants initially enrolled in a study designed to obtain

Correspondence to: J. Damilakis

Table 1. Characteristics of study population

	Farmers (n = 71)	Controls (n = 78)
Age (years)	51.8 ± 5.5	52.3 ± 5.9
Weight (kg)	63.2 ± 6.6	64.7 ± 6.5
Height (cm)	155.9 ± 4.9	156.4 ± 5.0
BMI (kg/m^2)	26.0 ± 2.9	26.5 ± 3.3
YSM	5.1 ± 4.0	4.8 ± 3.7

normative bone mass data. Historical physical activity was assessed by a questionnaire developed by Kriska et al. [25]. The reliability of this survey instrument has proved to be good, considering the fact that a lifetime of activity is being measured. All women were asked about participation in leisure time physical activities during four past age periods: ages 14–21, 22–34, 35–50, and 50+ years. None of the women in the control group had ever participated in any kind of regular or organized sport activity. Those who engaged in any heavy outside work (e.g., gardening) were excluded. Four women (5%) smoked, but none smoked more than 10 cigarettes per day. None of the subjects was taking estrogens, corticosteroids, or other medications known to affect bone mass or calcium metabolism. Women with a history of hypoparathyroidism, hyperparathyroidism, or any other metabolic bone disorder were excluded. All women completed a 4-day food record from which their daily calcium intake was estimated. No significant differences between farmers and controls were found in mean daily calcium intake (899 ± 370 mg/day for controls versus 892 ± 361 mg/day for farmers). None of the women consumed alcohol more than once a week. Table 1 shows the basic characteristics of the subjects included in the study.

Bone Mineral Density Measurements

BMD was measured at two sites—the lumbar spine (L-1 to L-4) (BMD_s) and the femoral neck using DXA (Hologic QDR-1000 Plus, Waltham, MA, USA). The long-term *in vitro* reproducibility of the system was estimated by scanning a spine phantom. The coefficient of variation (cv) was 0.3%. Short-term reproducibility was assessed by recording 27 independent measurements in a volunteer. The cv was 0.8% for anteroposterior spine measurements and 1.3% for femoral neck.

Ultrasound Measurements

BUA and SOS measurements were performed by a commercial computer-controlled transmission imaging system (Ubis 3000, DMS, France). BUA images were obtained by scanning the calcaneus with a pair of focused transducers, one acting as ultrasonic transmitter and the other as receiver, submerged into a water bath maintained at 30°C. The scan size was 60 mm × 60 mm. BUA imaging enabled standardization of a region of interest (ROI). An algorithm automatically selected a circular ROI of 15 mm in diameter located in the area of lowest attenuation in the posterior part of the calcaneus. BUA and SOS values were obtained by averaging the readings in the ROI. The short-term *in vivo* precision of the scanner was assessed in a previous study [26] consisting of five successive measurements in 10 healthy women. Root mean square cv of 1.35% and 0.24% were found for BUA and SOS, respectively.

Statistical Analysis

The results are presented as means ± SD. The significance of differences of anthropometric, densitometric, and ultrasound values between the farmers and the controls were examined with the Student's *t*-test. Linear regression analysis was performed to examine the correlations between BMD, BUA, SOS, and age in subjects undertaking heavy work and sedentary women. Analysis of covariance was used to compare the slopes of the regression lines. The statistical analysis was accomplished using the Statistical Analysis System (SAS Institute, Cary, NC) software package. A P value <0.05 was required to consider a test significant.

Results

Ultrasound values of calcaneus, spine BMD, and femoral neck BMD for the farm workers and the control group are shown in Table 2. Farm workers had significantly higher attenuation and velocity values compared with controls but body mass index (BMI) and weight in farm workers were less than those in age-matched controls. A significantly higher BMD at the spine and femoral neck was also found in women undertaking heavy work than in sedentary women. Table 2 also shows the differences in BUA, SOS, and BMD between farmers and controls relative to SD of the farmers. Figure 1 shows the relationship between bone status indices and age in farmers and controls. The regression equations of bone indices on age are given in Table 3. When the slopes of the regression lines of controls were compared with the slopes of the corresponding regression lines of farmers no significant difference was found. Ultrasound variables, spine BMD, and femoral neck BMD were also plotted against years since menopause (YSM). For all correlations the slopes of the regression lines for farmers and sedentary women were not significantly different.

Discussion

Study of groups of occupants undertaking heavy work offers a means of examining the relationship between bone density and physical activity. Hu et al. [17] categorized women into different physical activity groups on the basis of daily activity. Those undertaking a heavy labor had increased bone mass at the radius compared with those doing light and medium work. Recently, Joakimsen et al. [27] reviewed published studies that have focused on physical activity related to hip fractures. All studies suggest a strong protective effect of physical activity in leisure time against hip fractures. However, occupational physical activity seems to be less protective against hip fractures than activity in leisure time. The results of the present study demonstrate a positive effect of long-term physical activity on bone. Women undertaking heavy labor work have higher BMD values of the lumbar spine and femoral neck and higher BUA and SOS values of the calcaneus compared with controls. Our results also show that no significant differences in postmenopausal bone loss rate were found between farmers and sedentary women. However, in spine and hip, there was a tendency, although not significant, towards a greater postmenopausal bone loss rate of controls compared with farmers. Moreover, in all measuring sites, postmenopausal bone loss in farmers begins from a higher level compared with controls. This may have a positive influence on future fracture risk of these subjects.

Physical activity is frequently recommended as a way to help protect against bone loss or increase BMD during the postmenopausal period. Exercise effects on bone mass in postmenopausal women are probably site specific and load

Table 2. Ultrasound values and BMD measurements for farmers and control subjects

	Farmers (F)	Controls (C)	(F − C)/SD[a]
BUA (dB/MHz)	77.3 ± 7.9[b]	68.6 ± 7.4	1.1
SOS (m/sec)	1524 ± 21[b]	1509 ± 23	0.7
Spine BMD (g/cm^2)	1.030 ± 0.096[b]	0.907 ± 0.113	1.3
Femoral neck BMD (g/cm^2)	0.903 ± 0.090[b]	0.771 ± 0.099	1.5

[a] Standard deviation of the farmers; [b] $P < 0.0001$ versus controls

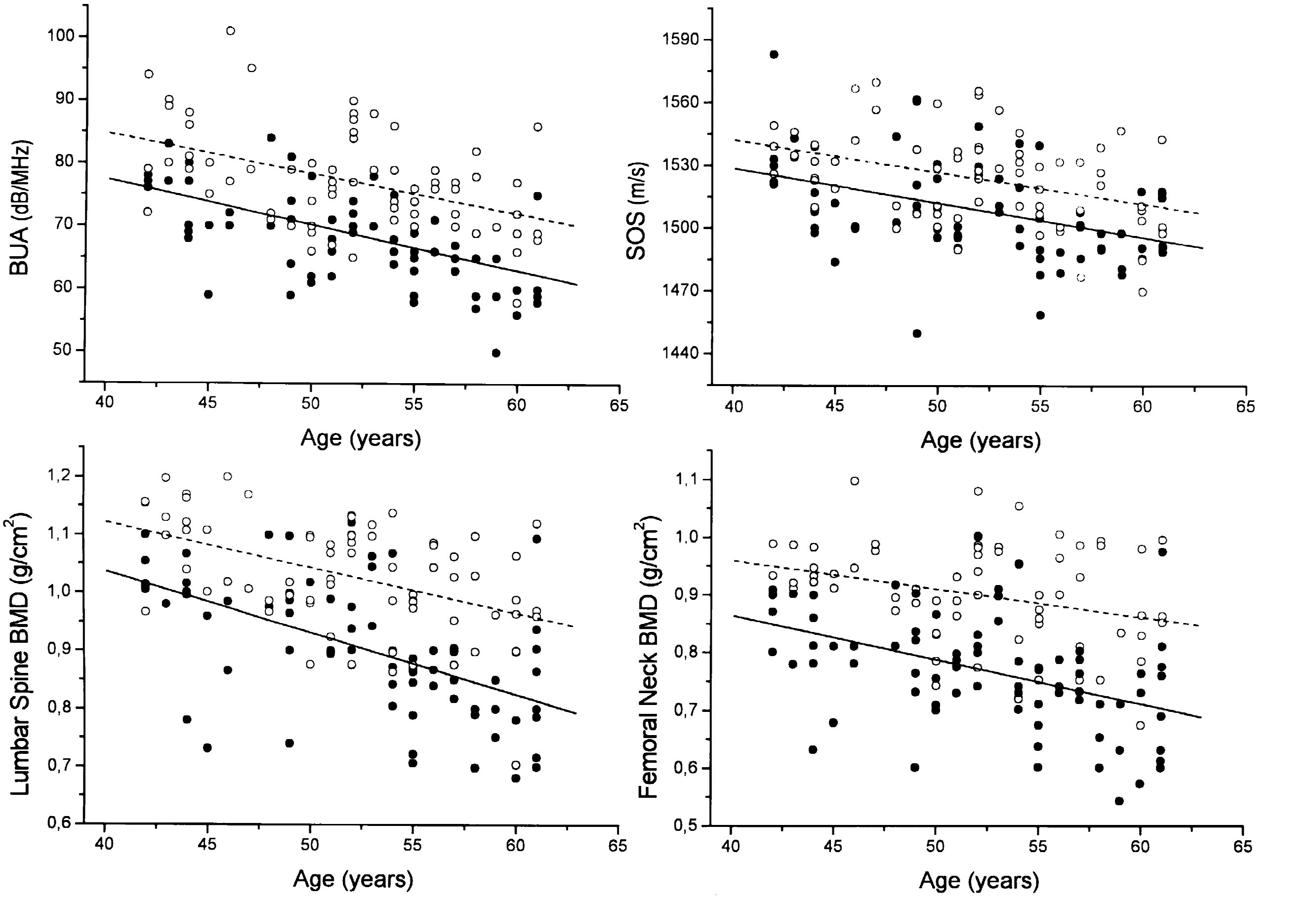

Fig. 1. Age-associated changes in BUA, SOS, BMD in the lumbar spine (L1–L4) and BMD in the femoral neck. The solid bands represent the regression lines for controls (●). The dotted bands represent the regression lines for farmers (○).

dependent. Kerr et al. [15] concluded that postmenopausal bone mass can be significantly increased by a strength regimen that uses high load low repetitions but not by an endurance regimen that uses low load high repetitions. Nelson et al. [28] demonstrated that 1 year of high intensity strength training has a positive effect on bone density in women 50–70 years old. Welsh and Rutherford [10] showed that high impact exercise, including step and jumping exercises specifically to load the proximal femur and spine, in postmenopausal women and men over 50 years old is feasible and effective at increasing proximal femur density but not spine or total body BMD. Bravo et al. [14] found that after 12 months, exercising can stabilize spinal bone density in postmenopausal women with low bone mass. The results of the present study support the hypothesis that loading should cause high stress in varied patterns on bone to produce an anabolic effect on bone mineralization. High muscular and gravitational forces acting on the skeleton during daily physical activity of farmers is associated with high strains in varied patterns that induce an osteogenic response in the hip, lumbar spine, and calcaneus. In contrast, long periods of repetitive loading causing low stress on bone was not effective enough to increase bone mass in newspaper carriers [19].

Several authors studied the calcaneus by densitometry to assess the effect of physical activity on BMD. Calcaneal BMD was increased after a 9-month marathon training program [29] and after vigorous exercise [30]. Athletes having

Table 3. Simple linear regression of bone indices over age

	Bone index	Equation	r
Controls			
	BUA (dB/MHz)	106.2–0.718 age	−0.57[a]
	SOS (m/sec)	1594–1.634 age	−0.42[a]
	Spine BMD (g/cm^2)	1.464–0.011 age	−0.56[a]
	Femoral neck BMD (g/cm^2)	1.170–0.008 age	−0.45[a]
Farmers			
	BUA (dB/MHz)	110.1–0.633 age	−0.44[a]
	SOS (m/sec)	1602–1.507 age	−0.39[a]
	Spine BMD (g/cm^2)	1.435–0.008 age	−0.45[a]
	Femoral neck BMD (g/cm^2)	1.155–0.005 age	−0.30[b]

[a] $P < 0.001$; [b] $P < 0.05$

a long-term training history and maintaining activity past 70 years of age preserve superior calcaneal bone mass compared with the average male population of the same age [31]. Childhood physical activity level has a significantly positive effect on bone density of the calcaneus [32]. These results support the concept that the calcaneus, a weight-bearing bone, appears to be very sensitive to mechanical stresses caused by physical loading. In contrast, the weightlessness experienced in space during orbital flight was shown to cause a decrease in the bone density of the calcaneus [33].

Our results indicate that the effect of physical activity on bone status can be studied using ultrasound measurements of the calcaneus. The differences relative to standard deviation between the group of farmers and the controls were greater in spine and femoral neck BMD than in BUA and SOS. However, densitometric and ultrasound variables were measured at different anatomical sites. Therefore, we do not know whether the greater discrimination ability of BMD measurements can be attributed to different loading of calcaneus compared with spine and femur, or to higher sensitivity of densitometric measurements as indicators of skeletal status compared with ultrasound variables.

In conclusion, the results showed that heavy manual work as a farmer is associated with a higher bone mass of the spine and hip and higher calcaneal BUA and SOS in healthy postmenopausal women aged 42–61 years. Postmenopausal status was associated with the same rate of bone loss for farmers and sedentary women.

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