Calcif Tissue Int (1998) 62:47–50

Calcified
Tissue
International

Occupational Sitting and Low Hip Mineral Density

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Received: 2 December 1996 / Accepted: 3 September 1997

Abstract. In order to evaluate the contribution of habitual physical activity to bone remodeling, we determined bone mineral density (BMD) at the lumbar spine (L2–4) and the hip by dual energy X-ray absorptiometry in 55 clerks and 44 nurses. Our data indicate similar L2–4 BMD in both groups due to equal weight load of the upper part of the body on the spinal column in both study groups, but higher femur BMD in the nurse group (0.6–0.8 SD, at various hip measurement sites) than in the clerk group. The age-adjusted hip BMD was correlated with serum osteocalcin levels, and was related to the duration of standing at work, indicating a cause and effect relationship. We conclude that prolonged working in a sitting position may induce a low hip BMD, and thereby increase the risk for osteoporotic hip fracture.

Key words: Bone mineral density — Deoxypyridinoline — Dual energy X-ray absorptiometry — Osteocalcin — Physical activity.

Osteoporosis (OP) is a condition of low bone mineral density (BMD) resulting in increased bone fragility and fracture rate [1]. Because medical treatments of OP have only a limited success, they are often expensive, and require medical monitoring, primary preventive measures are definitely preferred [2]. The mechanical function of the skeleton is to sustain gravity and facilitate motion, and therefore the main physiologic stimulator of bone integrity is mechanical loading [3]. Many cross-sectional and longitudinal studies [4] have revealed an increase in BMD induced by weight-loading exercise, and some of them even indicated a decrease in bone fracture rate [5]. However, the role of habitual physical activity in maintaining bone mineral mass is still unclear. Some studies suggested a salutary effect on BMD [6] whereas others reported no effect of daily physical activity on BMD [7]. In this study, hip BMD of hospital clerks who are employed while seated most of the day, was compared with that of the same hospital's nurses. Members of this latter group stand for long hours during the working day.

Materials and Methods

Subjects

Clerks and nurses employed for at least 5 years at The E. Wolfson Medical Center were recruited at random from the workers list. Women on estrogens, thiazides, corticosteroids, calcitonin, bisphosphonates, thione amides, thyroid supplementation, or antiepileptic medications were considered not eligible to participate in this study. Every volunteer completed a detailed questionnaire and was requested to fill out a record sheet for 1 week that contained her standing/walking time during the working hours, as well as the time afterwards. As there is no way to assess physical activity, leisure-time physical activity was retrieved from the volunteers' reports. All women then underwent a complete physical examination and had a venipuncture to determine osteocalcin, parathyroid hormone (PTH), and $250HD_3$ levels. Deoxypyridinoline excretion rate was determined in the second morning urine specimen. Finally, the participants were referred to bone mineral densitometry. Of 120 women who were approached, 5 were found not eligible as they were taking medications affecting bone, and 16 volunteers (10 clerks and 6 nurses) failed to make the appointment for the bone densitometry. The study was approved by the medical ethics committee, and every woman signed an informed consent.

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Bone Mineral Density

BMD of the lumbar spine (L2–4) and proximal femur and measured by dual energy X-ray absorptiometry (DeXA) using the Hologic QDR®-1000 instrument (Hologic, Inc., Waltham, MA). The coefficient of variation (CV) for BMD using the lumbar phantom was 0.47% and 0.98% and 1.1% for repositioned patients (L2–4 and hip, respectively). All measurements were performed by the same operator who was blind to the participants' occupation. As the cohort of subjects spans over a wide range of age BMD we expressed the results as age-adjusted Z score. This score was determined by the DeXA software based on the supplier's database.

Laboratory Tests

Blood samples were collected in glass tubes, and were allowed to clot at room temperature for 1 hour. Serum was separated by centrifugation, alliquoted, and kept frozen at −20°C until assayed. Urinary deoxypyridinoline levels were determined (Metra, Mountain View, CA) at a sensitivity of 1.1 nmol/liter. The intra- and interassay CV, at the relevant range, were 4.3% and 8.4%, respectively. The sensitivity of $250HD_3$ assay was 6.95 nmol/liter (Incstar, Stillwater, MN), the intra- and interrun CV were 5.6% and 15.6%, respectively. Intact PTH serum level were determined at a sensitivity of 0.11 pmol/liter (Nichols, San Juan Capistrano, CA). The intra- and interassay CV were 3.4% and 5.6%, respectively. Finally, osteocalcin serum levels were estimated (CIS, GIF-Sur-Yvette-Cedex, France) at a sensitivity of 0.08 nmol/liter and intra- and interassay CV were 3.7% and 6.6%, respectively.

Statistical Analysis

The number ratio of pre- to postmenopausal participants in both study groups as compared by Chi-square test; all other confound-

Table 1. Subject characteristics (mean ± SD)

Variable	Clerks (n = 55)	Nurses (n = 44)
Age (years)	47.2 ± 6.6	48.6 ± 7.6
Menopause state (pre/post)	36/19	23/21
BMI (kg/m^2)	25.7 ± 7.3	28.0 ± 0.2[a]
Smoking (pack × year)	6.4 ± 12.3	5.4 ± 13.0
Dietary calcium (mg/day)	590.9 ± 321.9	775 ± 342.8[b]
Leisure-time exercise (hours/week)	4.3 ± 9.0	2.8 ± 8.9
Menarche (years)	13.1 ± 1.4	13.2 ± 1.5
First delivery (years)	23.4 ± 3.8	22.8 ± 3.7
Deliveries (number)	2.5 ± 0.7	2.4 ± 1.0
Nursing (months)	5.1 ± 4.9	5.2 ± 5.9
OC[c] use (years)	1.2 ± 2.6	1.5 ± 2.7

BMI = body mass index
[a] $P = 0.014$; [b] $P = 0.008$; [c]OC = oral contraceptive

ing variables were compared by both the *t*-test and multiple linear regressions. Those that differed at α value of 0.05 or lower were further tested in analysis of covariance for a possible association with BMD. The correlations among BMD, serum osteocalcin levels, and the standing impact were assessed by computing the Pearson product-moment correlation coefficients. The statistical analyses was performed by using the STATISTICA® release 5 software (StatSoft®, Tulsa, OK).

Results

Subject Characteristics

The mean age of both study groups was similar (Table 1). The proportion of pre- to postmenopausal participants was not significantly higher in the group of clerks, as compared with the nurses ($P = 0.184$). The group of nurses had higher mean body mass index (BMI), as well as higher mean dietary calcium intake compared with the group of clerks. Leisure-time physical activity and cigarette smoking were comparably low in both groups. Various obstetric and gynecologic variables did not differ significantly in either study groups.

Bone Mineral Density

In accordance with the hypothesis of this study, age-adjusted lumbar spine BMD, expressed as Z score of the two study groups, was close (nurses −0.154 ± 1.116 SD, clerks −0.127 ± 1.370 SD, $P = 0.139$), indicating a similar gravitational load of the torso upon the spinal column independent of the employment posture. The distributions of femur neck BMD, and L2–4 BMD in the two study groups are shown in Figure 1. At all five measurement sites the mean age-adjusted BMD as higher in the nurses group than in the clerks' group: neck 0.520 ± 1.197 and −0.302 ± 1.097 SD, respectively ($P = 0.026$); trochanter 0.621 ± 0.996 and −0.411 ± 1.229 SD respectively, ($P = 0.022$); intertrochanteric region 0.626 ± 1.325 and −0.609 ± 1.230 SD, respectively, ($P = 0.025$); total hip area 0.499 ± 0.923 and −0.478 ± 1.066 SD, respectively, ($P = 0.021$); Ward's triangle 0.769 ± 1.071 and −0.661 ± 1.229 SD, respectively, ($P = 0.029$). Taking into account BMI and dietary calcium intake as covariates, lowered, but did not abolish, the statistical significance of these differences between the two study groups. After adjustment, the P values ranged between 0.037 at the intertrochanteric region and 0.047 at Ward's triangle.

In both groups, all five femur BMD measurement sites were highly correlated. The r values ranged between 0.58 (Ward's triangle-intertrochanter, nurse group), and 0.79 (total femur-intertrochanter, clerk group). Even after including the menopausal state of the participating subjects in the multivariate analysis of variance (MANOVA) analysis, the differences in femur BMD between the study groups were significant (Rao R(15,243), $P = 0.042$). At all sites, age-adjusted femur BMD positively correlated with the magnitude of the standing load (Fig. 2). The most significant correlation was observed at the femur neck region ($r = 0.466$, $P < 0.001$), and the lowest correlation was noted at the greater trochanter ($r = 0.32$, $P = 0.028$).

Biochemical Data

The levels of various indicators of bone metabolism and calciotropic hormones are shown in Table 2. Osteoblastic-marker osteocalcin serum level was higher in the group of nurses compared with the group of clerks whereas urinary deoxypyridinoline excretion rate reflecting osteoclastic activity was similar in both study groups. This may indicate the osteogenic stimulus by standing/walking upon the hip of the nurses' group. The association was further suggested by the positive correlation ($r = 0.246$, $P = 0.0169$) between serum osteocalcin levels and the estimated standing load (data not shown). Both serum 250HD$_3$ and PTH levels were similar in the two study groups, thus excluding an underlying metabolic bone disease as a confounding variable.

Discussion

The main findings of this study are an increased hip BMD in nurses whose work demands standing for considerable amounts of time as compared with clerks who sit most of the day. The total estimated time spent standing at work was correlated with both femoral BMD and serum osteocalcin level. These data suggest that even occupational body weight load stimulates hip mineralization. The two study groups were similar in age, menopausal status, and low levels of leisure-time activity. the nurses' group had a significantly higher mean BMI that contributes in part to the increased hip BMD observed in this group. This observation is in accordance with previous reports of correlation between BMI and BMD in both premenopausal [8] and postmenopausal subjects [9]. In this study we did not determine lean body mass nor muscle strength, both of which are thought to be the main osteogenic stimulus [10]. Thus, the mechanism by which higher nurse-group BMI contributes to the increased femur BMD is uncertain. In any case, inclusion of BMI as a covariant did not contradict our main conclusions. As the dietary calcium intake was higher in the nurse group, it is worthwhile noting that its role in affecting hip BMD is low in both axial and appendicular skeleton [11].

It is well accepted that the bone response to exercise is site specific [4]. The previous uncertainty as to the effect of exercise upon BMD may stem from not relating the type of exercise practiced, and the area at which BMD was determined. The main difference in the skeletal site upon which

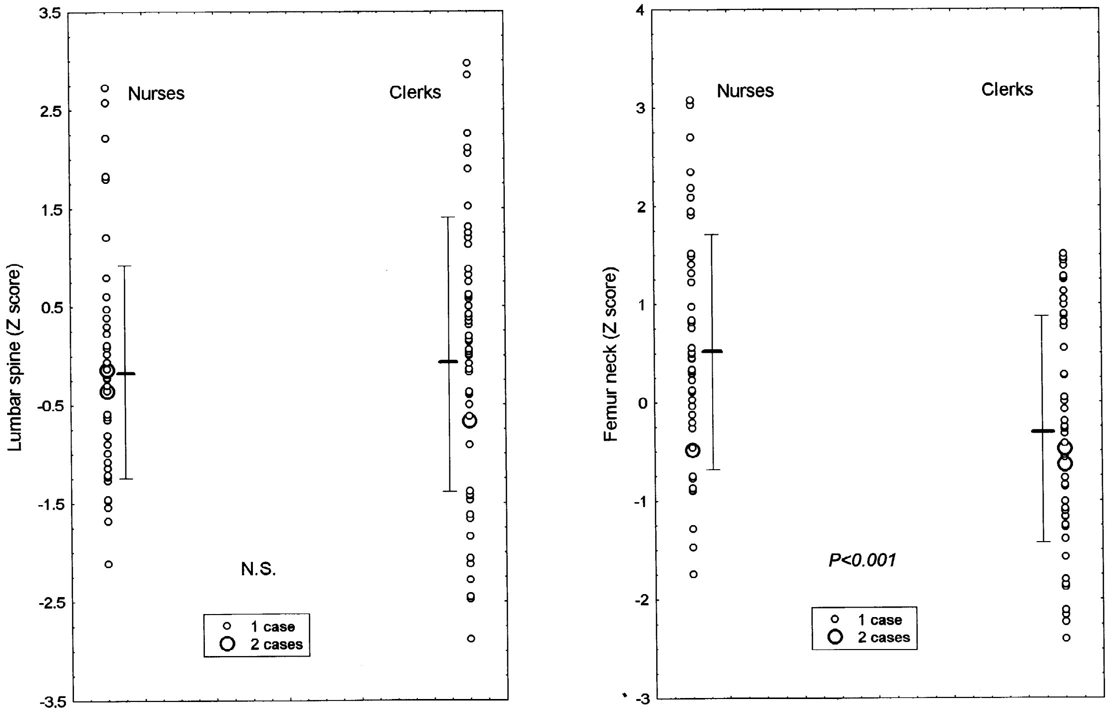

Fig. 1. Distribution of bone mineral density (BMD). The distribution of the age-adjusted BMD of the femur neck and lumbar spine (L2–4) are plotted separately for the group of nurses and the group of clerks. The vertical bars span over the SD: the horizontal thick lines indicate the mean values.

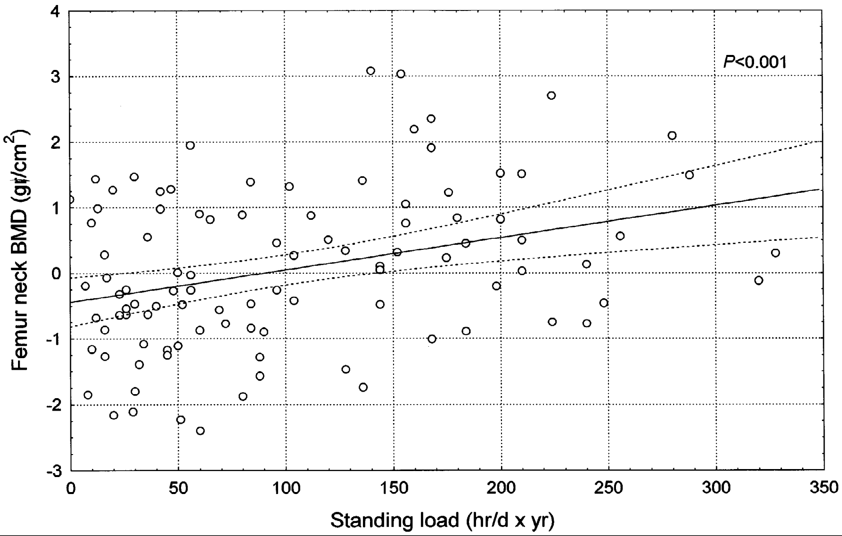

Fig. 2. Correlation between BMD and standing load. The correlation (solid line) and 95% CI (dotted lines) between age-adjusted femur neck BMD and the standing load expressed as the daily standing hours multiplied by working years is plotted together for the two study groups.

pressure is applied in exercising people as compared with sedentary people is the hip. This fact may explain our findings of increased femur BMD but not of L2–4 BMD. Similar conclusions were drawn by other studies [12, 13]. The idea that standing and/or walking are sufficient stimuli for hip mineralization correlates with some earlier studies evaluating the effect of walking and leisure-time activity upon the skeleton [9, 14]. However, other previous reports revealed no beneficial effect of standing/walking on BMD [7, 15]. The reason for this disagreement is not clear. As

Table 2. Biochemical data (mean ± SD)

Variable	Clerks (n = 55)	Nurses (n = 44)
Osteocalcin (nmol/liter)	0.84 ± 0.36	1.01 ± 0.42[a]
Deoxypyridinoline (nmol/μmol creatinine)	6.99 ± 2.13	6.87 ± 1.60
$250HD_3$ (nmol/liter)	80.92 ± 43.35	78.50 ± 31.08
PTH (pmol/liter)	1.93 ± 0.61	1.94 ± 0.82

[a]$P = 0.037$

BMD is determined by many inherent and acquired factors [16], the similar age-adjusted mean L2–4 BMD of the two study groups suggests stratification of these confounding variables, and therefore isolating the effect of occupational posture upon BMD. The type of load applied upon the hip by walking/standing of the nurses' group changes many times during the day. This is the type of strain that was described as most osteogenic [17], even though its magnitude may seem a trivial one. It is interesting that the osteoblast stimulation induced by walking/standing was measurable by the increased serum osteocalcin levels. Similar observations of higher secretion of osteocalcin in response to exercise was previously reported [18]. This association was further supported by the positive correlation between the estimated hip weight load applied and serum osteocalcin levels. This correlation suggests that the increased osteocalcin levels in the nurses' group is related to more nurses than clerks who are postmenopausal. As it has been reported, each standard deviation decrease in the hip BMD is associated with increased age-adjusted risk for hip osteoporotic fracture by a factor of 2.6. We may thus assume that the relative risk for hip fracture of the clerks' group as compared with the nurses' group is 1.5.

In summary, our study supports the idea that even working conditions contribute to the level of BMD, and therefore may affect the rate of osteoporotic hip fracture.

Acknowledgment. This work was supported by a grant from The Committee for Research & Prevention in Occupational Safety & Health of the Ministry of Labour & Social Affairs.

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