Effect of Physical Activity on Lumbar Spine and Femoral Neck Bone Densities

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Abstract


Accepted: November 1, 1988

The lumbar spine and femoral neck densities of 123 and 141 normal adult women (50 ± 10 years), respectively, measured by dual photon absorptiometry, were correlated with the number of hours of walking per day associated with their regular daily activities. This measure of exercise, obtained by detailed questionnaire and interview, was analyzed because it is regular, seasonally stable, and quantifiable. Both lumbar spine and femoral neck densities were significantly correlated with walking, with 0.8% and 1.9% increases in average bone density per hour of daily walking, respectively. This increase in density is substantial, considering that the age-related rate of bone loss in the same population is 0.7% and 0.5% per year of lumbar spine and femoral neck, respectively. This means that, on the average, a woman walking one additional hour per day has a femoral neck bone density comparable to that of a woman 4 years younger who does not pursue this additional activity. This physical activity-associated enhancement of bone density may be critical at old age when osteoporosis is clinically manifested.

Methods

Subject Population

Dual photon absorptiometry (DPA) BMD measurements of the LS and FN were conducted on ambulatory Caucasian women, aged 21-95 years, all residents of the Buffalo, NY area, solicited by community advertisement and physician referral. After excluding several groups of subjects because of a variety of abnormalities, a group of 201 normals, aged 24-79 years remained (13), the FN of which were available for statistical analysis. For reasons discussed elsewhere (13), we excluded from the analysis the LS of subjects below 35 and above 65, leaving a subpopulation of 151 women aged 35 to 65 years. The effects of menopause, the use of birth control pills, and the postmenopausal use of steroids on normal women were studied on the same population and no significant effects of these on bone density were found (13, 14). Consequently, we did not take these parameters into consideration in the analysis of the effect of walking activity on bone density. Physical activity data were gathered on 127 of the 151 normal LS group and 147 of the normal FN group. The other subjects were not available for the detailed interview about their daily physical activities. After exclusion of subjects who exercised excessively (see below), a group of 123 of the 151 normal LS and 141 of the normal FN were analyzed in this paper. All subjects gave their informed consent, as per the Internal Review Board of the State University of New York at Buffalo School of Medicine.
Bone Mineral Density

BMD of the LS and FN were measured by the NOVO BMC-Lab 22a dual photon densitometer (NOVO Diagnostics Systems, Denmark). For spine measurements, the patients' calves were supported to minimize lumbar lordosis. A foot support was used for hip measurement to restrict FN anteversion. Upon completion of the scans, they were checked for abnormalities. If found normal, the densities of the L2–L4 region in the vertebral column and the area between the head and the greater trochanter in the femur were calculated. Results were expressed as area BMD in units of grams of hydroxyapatite (g HA) per cm². The densities of both bones were normalized for age and those of the FN were also normalized for surface area. Surface area was calculated as height{$^2_{1.27}$} × weight{$^{1.7}_{4.25}$} × 7.184 × 10³ (Dubois). Height and weight were measured in cm and kg, respectively. The normalization factors were derived from regressions of BMD vs age and body surface area [LS BMD = 1.27 – 0.00864 × age, standard deviation (σ) = .098; FN BMD = 0.909 – 0.00401 × age, σ = .087; FN BMD = 0.572 + 0.19 × surface area, σ = 0.082] (13).

Blood Parameters

Blood samples were drawn with a minimum of stasis from recumbent subjects for serum level determinations. All blood was refrigerated within 1 h and spun down to serum within 24 h, then frozen at –70 °F until analysis could be performed. Albumin (ALB) and protein (PROT) were determined by the HABA dye method and refractive index, respectively (3). mmPTH was assayed by RIA (Immuno Nuclear Corp., Stillwater, MN). Free T₄ index (FT₄I) was calculated as the product of T₂ and T₃U, both determined by RIA (Bio-Rad, Cambridge, MA). Hematocrit (HCT) was measured by Coulter Counter. Total and ionized calcium were determined potentiometrically (3). Alkaline phosphatase (ALP), creatinine (CRT), magnesium (MG), phosphate (PHOS), glucose (GLU), cholesterol (CHOL), HDL cholesterol (HDL), blood urea nitrogen (BUN), total bilirubin (BILI), serum glutamic oxaloacetic transaminase (SGOT), and serum glutamic pyruvic transaminase (SGPT) were measured by Ectachem and SMAC autoanalyzers.

Physical Activity Parameters

A physical activity profile was devised in which the numbers of hours of walking per day associated with routine daily activities were recorded and calculated. "Walking" refers to moving about by foot at variable rates, while being fully upright and weight-bearing, during the course of participating in activities of daily living. This was based on a questionnaire, administered by an interviewer, which detailed periods of work, sleep, exercise, and any other activities which constituted a typical 24 h period for each subject, with 1 h blocks being the smallest periods assessed.

Daily walking, the way "walking" was defined above, is a standard, regular activity, and the amount of time of walking can be readily quantified. It also tends to be rather constant throughout the year, with minimal seasonal variation. Other forms of exercise not associated with normal daily activities were recorded but not included in the analyses because of the inherent problems involved in attempting to equate the many athletic endeavors in which people engage. We also observed that the quantity of exercise our subjects did was closely related to their daily walking amount (P = 0.009; R = 0.22) and, thus, was not an independent parameter. However, to minimize the possibility that the effects of additional exercise would influence the analysis of our walking results, we removed from the analysis subjects who exercised excessively over and above normal activities (greater than 10 h/week running, swimming, biking, etc.).

To avoid covariances, we regressed hours of walking against age, height, weight, and surface area (Table 1). Hours of walking per day were negatively correlated with age (hours of walking/day = 9.65 –0.05 × age; N = 141; σ = 2.16), but showed no relationship with height or weight. Since both LS and FN BMD were normalized for age (see above), there was no need to also normalize hours of walking for the same parameter. The descriptive parameters of these variables, LS and FN BMD, and walking hours are given in Table 2.

Definitions

The following definitions were used to describe the history parameters. Tobacco usage was separated into three categories—current smokers, ex-smokers, and those women who have never smoked. Alcohol usage was evaluated on a scale of low, medium, and high, with low equal to < 1 dring/week and high equal to > 10 drinks/week. Calcium supplementation was recorded in terms of dosage, type, and duration; since virtually all calcium preparations were identified as calcium carbonate, calcium types were not analyzed separately. Lactose intolerance refers to a subject-reported intolerance. Arthritis was coded positive if the subject reported arthritic-type pain in the joints or back.

A family history of osteoporosis was deduced from careful questioning of the subject regarding osteoporotic manifestations in other female members of her family, both
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Table 3 Bone density vs blood parameters

<table>
<thead>
<tr>
<th></th>
<th>LS density&lt;sup&gt;a&lt;/sup&gt;</th>
<th>FN density&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P (α)</td>
<td>P (β)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>BUN</td>
<td>.008</td>
<td>—</td>
</tr>
<tr>
<td>PROT</td>
<td>.68</td>
<td>0</td>
</tr>
<tr>
<td>ALB</td>
<td>.34</td>
<td>0</td>
</tr>
<tr>
<td>ALB/PROT</td>
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<td>0</td>
</tr>
<tr>
<td>PTH</td>
<td>.64</td>
<td>0</td>
</tr>
<tr>
<td>FT4I</td>
<td>.38</td>
<td>0</td>
</tr>
<tr>
<td>HCT</td>
<td>.36</td>
<td>0</td>
</tr>
<tr>
<td>ALP</td>
<td>.37</td>
<td>0</td>
</tr>
<tr>
<td>SGOT</td>
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<td>0</td>
</tr>
<tr>
<td>SGPT</td>
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<td>0</td>
</tr>
<tr>
<td>BILI</td>
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<td>MG</td>
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<td>0</td>
</tr>
<tr>
<td>PHOS</td>
<td>.75</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup>Normalized for age
<sup>b</sup>Normalized for age and surface area
<sup>c</sup>Effect cannot exceed 1% over the range of the variable with β = 0

Table 4 Lumbar spine and femoral neck density relationships with etiologic and dietary factors

<table>
<thead>
<tr>
<th></th>
<th>LS density&lt;sup&gt;a&lt;/sup&gt;</th>
<th>FN density&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P (α)</td>
<td>P (β)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1. Arthritis</td>
<td>.87</td>
<td>0</td>
</tr>
<tr>
<td>Lactose intolerance</td>
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<td>0</td>
</tr>
<tr>
<td>Family history of osteoporosis</td>
<td>.66</td>
<td>0</td>
</tr>
<tr>
<td>Calcium supplement</td>
<td>.55</td>
<td>0</td>
</tr>
<tr>
<td>Antacids</td>
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<td>0</td>
</tr>
<tr>
<td>Aspirin</td>
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<td>0</td>
</tr>
<tr>
<td>Fiber diet</td>
<td>.87</td>
<td>0</td>
</tr>
<tr>
<td>2. Alcohol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low vs medium</td>
<td>.80</td>
<td>0</td>
</tr>
<tr>
<td>Low vs high</td>
<td>.17</td>
<td>0</td>
</tr>
<tr>
<td>Medium vs high</td>
<td>.21</td>
<td>0</td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsmokers vs smokers</td>
<td>.33</td>
<td>0</td>
</tr>
<tr>
<td>Never smoked vs ever smoked</td>
<td>.10</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup>Normalized for age
<sup>b</sup>Normalized for age and surface area
<sup>c</sup>Effect cannot exceed 2% (I.) or 1% (II.) over the range of the variable with β = 0
<sup>d</sup>(1) and (2) refer to positive and negative reporting of the given factor in I., and 1st and 2nd parameter, respectively, in II.

Living and deceased; included were questions about loss of height, curvature of the spine ("hump"), and hip fractures.

Antacid usage was coded positive if it was more than occasional and involved formulations not calcium-based. Aspirin usage was coded positive if two or more aspirins (800 mg) were routinely taken per week. Supplemental fiber denoted the use of fiber preparations or specifically increased consumption of fiber-rich food over and above a normal diet.

Statistical Analysis

The statistical analysis, which included standard regression analysis with calculation of residuals, covariance analysis, and a calculation of both α and β two-tailed probabilities (P), is described elsewhere (13). All statistical analyses were performed on an IBM PC microcomputer using STATGRAPHICS ver. 2.0 (STSC Inc., Rockville, MD, 1987).
Results

Bone Density and Serum Parameters

Fourteen standard serum constituents were measured and analyzed for correlations with LS and FN BMD (Table 3). BUN was negatively correlated with LS BMD (LS BMD = 1.34 - 0.00548 \times \text{BUN}; \sigma = 0.093). All other \( P \) values were > 0.1, indicating lack of significant correlation. All \( \beta \) were equal to 0, indicating that if these serum parameters do affect or are affected by bone density, these effects would have to be minimal (< 1 of total bone density). Also, no relationships were found in our population between these parameters and walking activity. In all cases, if an effect were present, it could not exceed 2% change over the range of the variable with \( \beta = 0 \), i.e., if we missed an existing effect, this could not have changed the value of the corresponding variable by more than 2%.

Bone Density and History Parameters

Table 4 shows the results of comparing LS and FN BMD with alcohol and tabacco use. No significant differences were observed between the three groups of alcohol users. Bone densities were also compared between smokers and nonsmokers, and between women who used to smoke and those who never did. No significant associations between bone density and the use of tobacco were noted. Table 4 lists other history parameters that were compared with LS and FN BMD. None of these parameters showed any significant correlations with bone density.

Walking Activity and Bone Density

When the LS BMD of our subjects were compared with their walking hours per day, a positive correlation was found (Fig. 1, LS BMD = 1.20 + 0.00976 \times \text{walking hours}; \ R = 0.23; \ P = 0.01; \ N = 123; \sigma = 0.091). This corresponds to a 0.8% increase in LS BMD per hour of walking. When the same analysis was done for FN BMD (Fig. 2), a positive relationship was again observed (FN BMD = 0.50 + 0.00937 \times \text{walking hours}; \ R = 0.25; \ P = 0.003; \ N = 141; \sigma = 0.081). This represents a 1.9% increase in FN BMD per hour of walking.

Discussion

In the evaluation of our findings, we compare them only with the quantitative techniques of DPA, quantitative computed tomography, and X-ray spectrophotometry, since other bone density measurement methods have proved to be less accurate (8, 21).

When age-normalized LS BMD and age- and surface area-normalized FN BMD were compared with standard serum parameters, no significant correlations were found except for BUN, in agreement with Ismail et al. (15) for PTH and ALP. Since BUN is related to many body processes, such as nutritional balance, kidney clearance, and hydration state, it is difficult at this point to postulate a mechanism for the relationship between BUN and LS BMD. Calcium data will be presented elsewhere.

In our evaluation of the effects of alcohol on the BMD of our normal population, we excluded chronic alcoholics because of the extreme dietary and hormonal imbalances associated with this condition. We found no correlation between LS and FN BMD and ordinary levels of alcohol intake, in agreement with several other investigators (6, 24, 31). Feitelberg et al. (11) found lower LS BMD in chronic alcoholics, but their results may be of limited accuracy since they applied the normal curves of one DPA machine to data gathered by another instrument, possibly introducing a systematic error.

To correctly evaluate the effects of smoking on bone density, age normalization of data is essential. Otherwise, an apparent negative correlation between duration of smoking in years and bone density would readily appear since long-term smokers are obviously older, and would, therefore, have lower BMD regardless of their smoking status. When the age factor was taken into account, we found no significant relationship between smoking and LS BMD, in agreement with QCT (10) and other DPA (19) studies. Others reported,
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however, that osteoporotic women had a higher percentage of smokers among them than nonosteoporotic women (2, 5). Another variable not observed in our population may, therefore, exist. We also found no significant correlation between smoking and FN BMD, in agreement with several other studies (6, 17, 24), though again, one epidemiologic study indicated that tabacco smoking was a major risk factor for hip fractures (20).

Our average LS and FN BMD were not higher in women taking calcium supplements than in those not taking them, as also found by most other researchers (6, 9, 15, 23, 24, 28, 29). In a study based on X-ray analysis, Riggs et al. (27) observed lower vertebral fracture rates in women taking oral calcium. There may be, therefore, another factor besides bone density involved in this manifestation.

We found no significant correlations between LS or FN BMD and lactose tolerance, in agreement with Horowitz et al. (12). There were also no significant relationships noted between BMD and arthritis, family history of osteoporosis, or usage of antacids, aspirin, or supplemental fiber.

To evaluate the relationship between physical activity and bone density, we chose to concentrate on the effects that hours of walking had on LS and FN bone densities, since the walking associated with daily activities is a standard and regular form of exercise which is readily quantifiable.

Walking hours were analyzed with respect to age, height, weight, and surface area to check for covariances. Only age was significantly related to walking, with less walking noted as the age of the subjects increased. Since the effect of age on BMD was removed by normalization, no further correction was necessary.

As reported in the results section, both the LS and FN BMD of our subjects were significantly correlated with number of walking hours. We found changes in density of 0.8% and 1.9% for LS and FN BMD, respectively, per hour of daily walking. Using our previously reported annual bone loss rates for LS and FN (13), these percent changes correspond to a 1-year difference in LS BMD and a 4-year difference in FN BMD. In other words, for each additional hour per day that a normal woman walks, she retards her bone loss to an extent that her BMD data agree with the findings of Paganini-Hill et al. (24), who found a lower hip fracture prevalence in women who had a high frequency of participation in active outdoor games.

On the other hand, Dalén and Olsson (4) reported no significant differences between the LS and FN densities of small groups of male runners and nonrunners, but not only was this study restricted to males, additionally no mention was made of the daily physical activity of the nonrunners, making comparisons difficult. Lindquist et al. (19) reported no statistically significant differences in LS BMD between several levels of activity in women, but no supporting data were provided in their paper. Wysak et al. (32) stated that currently exercising women were not at lower risk of developing fractures throughout the body than nonexercising women, but they did not indicate the risk ratios of the specific bones. They also did not specifically define what “currently exercising” entailed. Drinkwater et al. (8) compared the LS densities of a group of eumenorrheic athletes with those of another group’s normals, but did not specify the statistical significance or non-significance of this comparison. Talmage et al. (30) measured the LS BMD of groups of athletic and nonathletic women, but an intergroup comparison was not done because of the small number of subjects in the former group.

We compared walking with several serum parameters associated with bone homeostasis, none of which were significantly correlated, in agreement with Kröner et al. (18) for total calcium phosphate, and alkaline phosphatase. Therefore, none of these seems to be involved in the enhancement of bone density by walking.

In conclusion, our data show meaningful positive associations between normal daily walking and both LS and FN BMD. Just one additional hour per day of walking as part of normal daily activities can greatly reduce the age-related bone loss which may lead to osteoporosis, providing a safe, effective, and no-cost strategy for helping to ward off this common debilitating disease.

Acknowledgment

Dr. S. I. Gutman of SUNY at Buffalo School of Medicine and Dr. A. Bhargava of Roswell Park Memorial Institute for their assistance in generating clinical laboratory data.

References


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