# Effects of Walking-only Interventions on Bone Mineral Density at Various Skeletal Sites: A Meta-analysis

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## ABSTRACT

**Background and purpose** Osteoporosis, a common disease in postmenopausal women and the elderly, is associated with decreases in bone mineral density (BMD) and fractures. As weight-bearing activity such as walking has the potential to maintain or increase BMD, I sought in this meta-analysis to mathematically consolidate research on the effects of walking interventions on BMD. **Methods:** A literature search for studies examining the effect of walking on BMD in postmenopausal women and men and women aged 50 years and older was conducted. Search strategies included online literature searches, hand-searches of journals, and examination of the reference lists of articles selected for inclusion. Effect sizes were calculated for each article selected for inclusion and a meta-analysis was conducted for these articles. **Results:** Ten articles met the inclusion criteria for the meta-analysis. Walking had a significant ($P < .03$) positive effect (.32) on lumbar BMD but not on the femur or the calcaneus**. Discussion and Conclusion:** The results of this meta-analysis do not suggest that walking interventions alone will limit demineralization at all skeletal sites. Perhaps other forms of exercise in addition to walking should be incorporated into training regimens for patients at risk for osteoporosis.

*Key Words***:** osteoporosis, walking, bone mineral density

## INTRODUCTION

Osteoporosis is a systemic skeletal disease that is marked by decreased bone mass and compromises in bone architecture. It is a common disease in postmenopausal women and the elderly, affecting approximately 75 million people in the United States, Europe, and Japan.[1] Decreases in bone mineral density (BMD) result in bone fragility and increased fracture risk. Osteoporotic fractures cause disability, pain, loss of independence, and decreased quality of life.[2] The costs of osteoporotic fractures were $17 billion in the United States in 2001.[3]

Researchers have proposed that maintaining physical activity in the later decades of life may slow age-related bone loss and reduce fracture risk.[4,5] Evidence in the literature links physical inactivity to bone loss.[4,6,7] Puntila et al reported the annual loss of lumbar spine BMD to be 23% less in physically active peri- and postmenopausal women; this loss is 52% less for lumbar BMD in women reporting walking or jogging as their sole form of weight-bearing exercise.[4] Walking activity is also positively associated with hip strength and lower risk of hip fracture.[7]

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While various forms of weight-bearing activity may slow loss of BMD or possibly increase BMD at various skeletal sites through mechanical loading of bone, walking as an exercise intervention is of particular interest. Brisk walking for exercise could easily be incorporated into a patient's current lifestyle and may be accepted by a broad range of patients.[8] A moderate walking protocol could easily be adhered to over the course of a patient's lifetime;[9] high compliance with walking programs has been reported.[10,11]

Several cross-sectional and descriptive studies indicate a positive relationship between walking and BMD at various skeletal sites such as the distal radius, trochanter, femoral neck, and the spine.[4,6,8,10,12] Some studies have examined the effect of walking duration and intensity on BMD. For example, Kitagawa et al[12] found that pedometer-recorded number of steps walked was positively correlated with BMD, while Thorsen et al[6] found that brisk outdoor walking for 90 minutes at 50% of $VO_2max$ had a significant positive effect on the markers of collagen metabolism.

These results[4,6,8,10,12] support walking as an effective method of increasing BMD. However, there is a need to determine if there is a threshold of exercise intensity necessary to increase bone mass[10] as there may be an optimal number of steps/day and walking speed necessary to maintain or increase BMD. The purpose of this meta-analysis of clinical trials was to determine the effect size of walking interventions on BMD at various skeletal sites.

## METHODS

### Search Strategy

Online literature searches were conducted through Medline, the Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Health Services, Technology, Administration, and Research (HealthSTAR). The search terms used were: 'walking,' 'bone mineral density,' and 'osteoporosis' and 'aerobic exercise,' 'bone mineral density,' and 'osteoporosis.' Ovid was used as the gateway search vehicle for both CINAHL and HealthSTAR. Online searches were limited to articles that were both written in English and reported controlled clinical trials. Hand searches were also conducted for potential articles published over the past 20 years in the *Journal of the American Geriatrics Society* and in the *Journal of Gerontology: Biological and Medical Sciences*. Hand searches were conducted in online issues of *Osteoporosis International* and *Calcified Tissue International* for the years 1996-2004. Additionally, issues from *Bone* for the years 1985-1992 and from the *Journal of Bone and Mineral Research* for the years 1989-2004 were searched for potentially relevant articles.

Because issues of *Bone* later than the year 1995 were available online, the online search terms that were employed for the Medline, CINAHL, and HealthSTAR were used to search *Bone* online for additional potential articles for the years 1995-2004. All reference lists of identified articles were checked for additional articles related to the meta-analysis. The final search was conducted on 12/17/04.

### Inclusion Criteria

In order for an article to be considered for inclusion in the meta-analysis, the study design had to be either a randomized clinical trial or a quasi-experimental clinical trial in which group assignment was not randomized. In order to target people at risk for primary (age-related and menopausal-related) osteoporosis, the sample had to consist of men and/or women 50 years of age and older or peri- or postmenopausal women. The intervention investigated in a study had to consist of a walking intervention-only group compared to either another form of exercise and/or a control group. A decision was made to include studies that paired walking with step-up exercises, provided the subjects did not use weights for this exercise. This decision was made because of the difficulty determining if subjects participating in home-based walking programs included walking stairs as part of their regimen. The outcome of increased BMD had to be confirmed via dual energy X-ray absorptiometry (DEXA-scan), computed tomographic imaging (CT) scan, or quantitative ultrasound.

### Data Extraction/Quality Assessment Form

Once an identified article was retrieved, data were extracted from the study in order to determine whether it met the criteria for inclusion in the review, the quality of the article, and the effect size for the study. The data extraction/quality assessment form is available upon request.

### Effect Size Calculation

Effect sizes and the corresponding confidence intervals were separately calculated for each article prior to pooling the effect size from each article in a meta-analysis. This was done to allow for each individual article to be examined based on its individual characteristics. This decision was based on the differences in sample sizes, walking interventions, and the inclusion of articles in which subjects were not assigned to groups randomly. Following individual effect size calculations, a combined effect size was also calculated for the effect of walking on lumbar BMD (found in 7 articles) and femoral neck BMD (found in 5 articles) and calcaneal BMD (found in 2 articles).

### Data Analysis

Data were initially analyzed using formulas written into a Microsoft ® Excel (Microsoft Corp., Seattle, WA) spreadsheet. The effect size index, or Cohen's d, was calculated using the following general formula:[13]

$$d = \frac{\bar{X}_{experimental\ post} - \bar{X}_{control\ post}}{s_{pooled}}$$

where $\bar{x}_{experimental\ post}$ is the post-test mean of the experimental group, $\bar{x}_{contril\ post}$ is the post-test mean of the control group, and $s_{pooled}$ is the square root of the average of the squared standard deviations.[13] Adjustments were made to the formula for Cohen's d to account for data that were presented as change scores versus pre and post data. Confidence intervals (set for 95% confidence) for the effect size were calculated using the following general formula[13]:

$$95\%\ CI = d +/- 1.96 \times SE_d$$

$$\text{where } SE_d = \sqrt{\frac{n_{experimental} + n_{control}}{n_{experimental} \times n_{control}} + \frac{d^2}{2\,(n_{experimental} + n_{control})}}$$

in which $n_{experimental}$ is the number of subjects in the experimental group, $n_{control}$ is the number of subjects in the control group, and d is the effect size. The effect size represented by Cohen's d can be interpreted as small (**0**.2), medium (**0**.5), or large (**0**.8 and higher).[13] Additionally, the sign of Cohen's d provides information about the results of the study. A positive value means that the experimental group had a higher post-test mean than the control group. A negative value indicates the control group had a higher mean than the experimental group.[13]

The meta-analysis excluded articles describing BMD of the proximal and distal forearm[14] and the distal radius,[9] as these sites are not logically tied to the walking. Meta-analysis was conducted using a DOS-based program[15] that weighted each effect size by the size of the sample. The meta-analysis program forced the user to choose the most important comparison, rather than allowing the combination of multiple comparisons from the same study. For this reason for Brooke-Wavell et al[11] walkers in the cross-over control group were compared with sedentary controls as these groups had not been compared in their earlier study;[16] for Hatori et al,[17] the high-intensity group was used versus the moderate intensity group as this group had the higher effect size.

## RESULTS

### Included Articles

Ten articles met the criteria for inclusion in the meta-analysis. Using the search terms 'walking' and 'bone mineral density' and 'osteoporosis' yielded 3 articles[9,17,18] from Medline and 2[10,19] from HealthSTAR and 1[19] from CINAHL. Using the search terms 'aerobic exercise' and 'bone mineral density' and 'osteoporosis' yielded 1 article in Medline and 2[10,19] in HealthSTAR. Three articles[14,16,20] were found in the reference lists of other articles. Two articles[11,21] were found from hand searches of *Calcified Tissue International* and *Osteo-porosis International*, respectively. Table 1 provides information regarding the sample and intervention for each article included in the meta-analysis.

Fifty-four articles originally identified through the various search strategies did not meet the inclusion criteria for the meta-analysis. A list of articles excluded from the meta-analysis is available upon request.

### Effect Size Calculations

Results from individualized effect size calculations indicated a wide range of effect sizes (-1.31 to 2.77) across the 10 studies (Table 3). Additionally, these results reflected positive

**Table 1. Articles Included in the Meta-analysis**

| Study | Included Subjects | Mean Age (years) or Reported Age Range | Sex | Health Status | Walking Intensity | Walking Frequency and Duration | Exercise Setting | Design |
|---|---|---|---|---|---|---|---|---|
| Brooke-Wavell et al[16] 1997 | 84 | 60-70 | Female | Post-menopausal | Moderate to high "brisk" walking based on heart rate | 280 min/week | Primarily home-based | RCT, no information on blinding |
| Brooke-Wavell et al[11] 2001 | 53 of 68 subjects* | 60-70 | Female | Post-menopausal | Moderate to high "brisk" walking based on heart rate | 280 min/week | Primarily home-based | Quasi-experimental, groups not randomly assigned, no information on blinding |
| Cavanaugh and Cann[20] 1988 | 17 | 49-64 | Female | Post-menopausal | 60-85% of age-adjusted heart rate maximum | 40 min, 3x/week, 52 weeks | Supervised | Quasi-experimental, groups not randomly assigned, no information on blinding |
| Chien et al[10] 2000 | 18 | 48-65 | Female | Post-menopausal | 30 min at 70-85% $VO_2$ max | 50 min, 3x/week, 24 weeks | Supervised | Quasi-experimental; groups not randomly assigned; no information on blinding 10 minute step-ups on 20-cm high bench |
| Ebrahim et al[18] 1997 | 97 | 59-76 | Female | Post-menopausal women with a proximal humeral fracture in past 2 years | Moderate "Brisk" pace that did not cause discomfort or shortness of breath | 40 min, 3x/week, 104 weeks | Home-based | Single-blinded RCT; monthly telephone calls to monitor compliance |
| Hatori et al[17] 1993 | 21 of 33 subjects* | 45-67 | Female | Post-menopausal | Moderate Intensity Group: 90% of anaerobic threshold; High Intensity Group: 110% of anaerobic threshold | 30 minutes, 3x/week, 7 months | Home-based, flat, grass-covered ground | RCT; no information on blinding |
| Huuskonen et al[19] 2001 | 132 | 50-60 | Males | Random sample of Finnish men, health status not reported | 40-60% of $VO_2$ max | 30-45 min, 3x/week, 3 months; then 60 minutes, 5x/week, 45 months | Home-based | RCT; no information on blinding |
| Martin and Notelovitz[14] 1993 | 55 | 50-65 | Females | Post-menopausal | 70-85% of maximum heart rate | 30 or 45 min, 3x/week, 12 months | Supervised | RCT; no information on blinding; two durations: 30-minute and 45- minute session |
| Nelson et al[9] 1991 | 36 | 60.2 +/- 6.5 | Females | Post -menopausal | 75-80% of maximum heart rate | 50 min, 4x/week, 52 weeks | Supervised | Double-blind, RCT; 3.1 kg weight belts used, calcium drinks provided, no random assignment |
| Sandler et al[21] 1987 | 255 | 57 | Females | Post-menopausal | No mention of intensity | At least 7 miles/week | Home-based, with the option of group exercise | Partially randomized; no information on blinding; 26 women assigned to groups based on friend's assignment |

*Number of subjects included in review differs from number of subjects in study sample due to exclusion of non-applicable subject groups.

effect sizes, indicating the experimental group had higher post-test means than the control group, negative effect sizes, indicating that the control group post-test means were higher, and no effect size.

**Meta-Analysis**

Results from the 3 meta-analyses for the combined effect sizes for the lumbar spine, femur, and calcaneus showed a significant ($P < .03$) positive effect (.32) of walking on lumbar BMD. No effect was noted for walking on femur BMD. A positive (.32) but nonsignificant ($P<.56$) effect on calcaneus BMD was found (Table 3). Results for each of the meta-analyses can be found in Table 3. Homogeneity of effect sizes was found across all groups, as evidenced by the Chi-square tests for homogeneity for the lumbar spine, femur, and calcaneus ($P < .28$, $P <1.00$, $P < .19$, respectively).

**Table 2. Effect Size and Confidence Intervals of the Selected Articles**

| Article | Effect Size (d) on BMD | | 95% Confidence Interval |
|---|---|---|---|
| Brooke-Wavell et al[21], 1997 | Lumbar Spine | 2.77 | (2.42, 3.08) |
| | Femoral Neck | .84 | (.5, 1.16) |
| | Calcaneus | 2.77 | (2.42, 3.08) |
| Brooke-Wavell et al[12], 2001 | **Original Walking Intervention Group** | | |
| | Lumbar Spine | -.166 | (-2.16, -1.1) |
| | Femoral Neck | -.64 | (-1.16, -.09) |
| | Calcaneus | -1.31 | (-1.82, -.76) |
| | **Cross-over Control Group** | | |
| | Lumbar Spine | -.255 | (-3.01, -1.99) |
| | Femoral Neck | -.77 | (-1.26, -.24) |
| | Calcaneus | .87 | (.35, 1.37) |
| Cavanaugh and Cann[22], 1988 | Lumbar Spine | .38 | (-.46, 1.17) |
| Chien et al[11], 2000 | Lumbar Spine | .34 | (-.28, .97) |
| | Femoral Neck | .94 | (.2, 1.6) |
| Ebrahim et al[18], 1997 | Lumbar Spine | 0 | (-.29, .29) |
| | Femoral Neck | .46 | (.16, .74) |
| Hatori et al[19], 1993 | **Moderate Intensity** | | |
| | Lumbar Spine | .24 | (-.53, .98) |
| | **High Intensity** | | |
| | Lumbar Spine | 1 | (.34, 1.59) |
| Huuskonen et al[20], 2001 | N/A* | | N/A* |
| Martin and Notelovitz[16], 1993 | **30 Minute Duration** | | |
| | Lumbar Spine | .02 | (-.61, .65) |
| | Proximal Forearm | -.01 | (-.63, .62) |
| | Distal Forearm | -.18 | (-.81, .45) |
| | **45 Minute Duration** | | |
| | Lumbar Spine | .1 | (-.56, .77) |
| | Proximal Forearm | .06 | (-.6, .73) |
| | Distal Forearm | .06 | (-.6, .73) |
| Nelson et al[10], 1991 | **Moderate Calcium/Walking Group** | | |
| | Lumbar Spin | -.5 | (-1.44, .44) |
| | Femur | -.05 | (-.97, .87) |
| | Distal Radius | -.32 | (-1.25, .61) |
| | **High Calcium/Walking Group** | | |
| | Lumbar Spine | .16 | (-.77, 1.08) |
| | Femur | .83 | (-.13, 1.8) |
| | Distal Radius | .43 | (-.51, 1.36) |
| Sandler et al[23], 1987 | N/A* | | N/A* |

*Authors of these articles reported that no effect from the walking intervention was found, but did not report means and standard deviations from control and intervention group

Results of individual effect size calculations were variable for the 10 articles included in this meta-analysis. Some included studies showed large positive effects at the femur,[9,10,11,16] lumbar spine,[16,17] and calcaneus,[11,16] while others ranged from negative effect sizes (which indicates that the control group had better BMD values in comparison to the walking-intervention group) to a moderate positive effect size. Despite the large positive effects that were found in some of the studies, the results of the meta-analysis yielded only one significant small effect size of walking on BMD at the lumbar spine. These results are in contrast to the results of another meta-analysis of 3 articles[14,17,18] which examined the effects of walking on BMD,[22] which found a positive effect of walking on BMD of the spine (1.31) and hip (.92). Inclusion of nonrandomized articles in the present meta-analysis may underlie the difference. For example, a meta-analysis examining the effects of exercise training programs found effect sizes to be twice as high in nonrandomized versus randomized trials.[23] The small or absent combined effect sizes found in the present meta-analysis were most likely due to large differences in methods and sample size, which would have resulted in some studies being weighted more heavily than others. The confidence intervals for all of the studies exhibiting large effect sizes were quite wide with the exception of that of Brooke-Wavell et al;[16] this is most likely due to the small sample size that these studies used. Additionally, some studies such as those of Hatori et al[17] and Cavanaugh and Cann[20] produced effect size confidence intervals with a negative lower bound for the lumbar spine and in some instances with both negative upper and lower boundaries, such as most of the effect sizes calculated for Brooke-Wavell et al.[11] These negative confidence intervals suggest that the studies were not sufficiently powered yield a significant effect size. These limitations of both broad confidence intervals and under-powered studies may have affected the ability to detect a considerable overall combined effect size for the lumbar spine, femur, and calcaneus.

## DISCUSSION

This meta-analysis examined the effects of a walking intervention on BMD in subjects at risk for primary osteoporosis. The ease at which a walking program could be incorporated into the lifestyle of patients at risk for skeletal demineralization formed the rationale for examining walking-only interventions.

Six of the 10 studies[11,16-19,21] consisted of unsupervised walking interventions. These studies relied on training diaries and self-report for walking pace and heart rate.

**Table 3. Meta-Analysis Results**

| | Lumbar Spine | Femur | Calcaneus |
|---|---|---|---|
| Number of studies | 8 | 5 | 2 |
| Subject N | 362 | 285 | 115 |
| Average effect size | .3131 | .00 | .3155 |
| Average effect size SD | .3361 | .00 | .4462 |
| t-test of effect size | 2.6348 | .00 | 1.00 |
| p-value of t-test | .03 | 1.00 | .56 |
| Fail safe N | 7 | N/A* | N/A* |
| Average d | .32 | .00 | .3186 |

*The fail safe N is the number of studies with 0 effect size that would need to be added to the analyses to make a significant effect size no longer significant. As such, it is only calculated when the t-test for effect size is significant.

Questions have been raised as to whether reliability estimates of subjects' self-reported physical activity are accurate and to whether individual exercise intensity levels are accounted for in the self-reports.[24] Self-report of physical activity has been found to be less stable than self-report for physiologic measures of blood pressure and cholesterol scores.[25] Median convergent validity of self-reported activity level and pedometer readings has been reported as low.[26] Differences may have existed between actual and reported duration and intensity of the unsupervised walking, which too may have effected upon the ability to detect an overall effect size.

Several limitations to this meta-analysis should be acknowledged. The first is that only articles written in English were included in this study. English-language journals tend to report positive results.[27] However, it should be noted that several of the articles[19-21] included in this review reported interventions to have negative or null effects. The inclusion and exclusion criteria chosen prior to the start of this meta-analysis may also be a limitation. The inclusion of articles that incorporated other forms of aerobic exercise would have yielded more articles. For example, both Wolff et al[23] and Berard et al[28] found significant effects for physical activity at various skeletal sites, by including articles that investigated forms of exercise other than walking. However, the aim of the present study was to investigate if walking had an effect on BMD at various skeletal sites; inclusion of other forms of exercise would have made the results of the meta-analysis more difficult to interpret with respect to walking interventions. Four limitations exist with respect to the search strategies. The Science Citation Index and Embase databases were not used in this meta-analysis. The use of these 2 databases would have made the search more comprehensive. However, hand searches of journals and of the reference lists of journal articles yielded only an additional 5 articles, which may indicate that the search was reasonably comprehensive in scope. Another limitation was the restricted number of issues available for hand searching for *Bone*, *Calcified Tissue International*, the *Journal of Bone and Mineral Research*, and *Osteoporosis International*. It would have been preferable to have hand searched issues from the past 20 years of issues for these journals. A third limitation related to the search strategy employed may be related to keywords used to retrieve articles. Three articles[14,16,20] were found in the reference lists of other articles and 2[11,21] were found by hand searching journals. All of these articles had the words 'postmenopausal women' in the title. This term was not used in the initial search in order to retrieve any articles investigating age-related osteoporosis in males. The meta-analysis program used for this study must be acknowledged as a final limitation, as it did not provide confidence intervals for the effect sizes.

## CONCLUSION

This meta-analysis failed to demonstrate a meaningful effect size for walking interventions, despite descriptive studies such as that of Kitagawa et al[12] which demonstrate a relationship between walking and BMD. One reason may be the variable procedures for the walking interventions in the articles that met the inclusion criteria; another may be the confounding due to the inclusion of nonrandomized and partially trials. A large randomized clinical trial in which patients are supervised during treadmill training or are unsupervised with a brisk walking pace operationally defined is necessary to determine if further investigation into the effects of walking training on BMD is warranted. Preliminary results do not support the use of walking-only interventions to maintain BMD; other forms of exercise should be incorporated into training regimens for patients at risk for primary osteoporosis.


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