

Brisk walking reduces calcaneal bone loss in post-menopausal women

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(Received 23 April/29 July 1996, accepted 19 August 1996)

1. This study examined the influence of brisk walking on skeletal status in post-menopausal women.

2. Subjects were 84 healthy women aged 60–70 years who were previously sedentary and at least 5 years post-menopausal. Subjects were randomly assigned to walking ($n = 43$) and control ($n = 41$) groups. Walkers followed a 12-month, largely unsupervised programme of brisk walking. The bone mineral density of the lumbar spine, femoral neck and calcaneus and broadband ultrasonic attenuation of the calcaneus were measured at baseline and after 12 months.

3. Forty control subjects and 38 walkers completed the study. Walkers built up to 20.4 ± 3.8 min/day (mean \pm SD) of brisk walking. Body mass increased in control subjects relative to walkers [mean change (SE) $+0.9$ (0.3) and -0.1 (0.3) kg respectively; $P = 0.04$]. Predicted maximum oxygen uptake increased in walkers by 2.1 (0.9) ml min $^{-1}$ kg $^{-1}$ ($P = 0.02$). Bone mineral density in the lumbar spine and calcaneus fell in control subjects [-0.005 (0.004) and -0.010 (0.004) g/cm 2 , respectively] but not in walkers [$+0.006$ (0.004) and $+0.001$ (0.004) g/cm 2]. The difference in response between groups was significant in the calcaneus ($P = 0.04$) but not in the lumbar spine ($P = 0.08$). Mean femoral neck bone mineral density did not change significantly in either group, although changes in walkers were related to the amount of walking completed ($r = 0.51$, $P = 0.001$). The change in broadband ultrasonic attenuation of the calcaneus differed between groups [control subjects, -3.7 (0.8); walkers, -0.7 (0.8) dB/MHz; $P = 0.01$].

4. Walking decreased bone loss in the calcaneus and possibly in the lumbar spine. It also improved functional capacity and enabled walkers to avoid the increase in body mass seen in control subjects.

and serious disability, with many hip fracture victims becoming dependent on others [3]. In addition to the human costs, financial costs to the National Health Service (NHS) are high, for example an estimated £742 million in 1992–93 [3]. Potential preventive strategies are therefore of interest and should be evaluated. Among these is physical activity, which, when undertaken regularly, has been reported to be associated with a reduced risk of fracture [4]. Almost 50% of women have experienced a fracture by the time they reach 70 [3], but it is not known whether exercise regimens that are widely acceptable to women in the age group at risk are effective.

Observational studies show that regular walkers experience a reduced risk of fracture at the hip [5]. This association could, however, be explained by better health status in these individuals. Intervention studies in post-menopausal women have usually examined the influence of *brisk* – as opposed to normal-paced – walking on indices of bone. They have yielded conflicting results [6–11]. Three studies were randomized; one reported a significant increase in bone mineral density (BMD) at the lumbar spine [10], whereas two found no effect [6, 11], although in one of the two studies measurements were made at a non-load-bearing site [6]. Most studies involved fewer than 20 subjects per group [7, 9–11], with correspondingly low power to detect small changes in bone. Consequently, there is no basis at present for clinical or public health [12] recommendations regarding walking in osteoporosis prevention.

The purpose of the present randomized, controlled study was therefore to examine the influence of brisk walking on indices of bone mineral status in healthy post-menopausal women. The study was of 12 months' duration, long enough to reveal adaptive remodelling and to control for seasonal effects. Changes in bone were measured using dual energy X-ray absorptiometry and, in addition, by broadband ultrasonic attenuation (BUA) so that the potential of this technique to detect changes in bone could be assessed. Measurements were made at the

INTRODUCTION

Osteoporotic fractures of the hip and vertebral bodies are associated with increased mortality [1, 2]

Key words: bone mineral density, exercise, osteoporosis/prevention, post-menopausal women, ultrasound, walking.

Abbreviations: BMD, bone mineral density; BUA, broadband ultrasonic attenuation; DXA, dual X-ray absorptiometry.

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calcaneus – the site of ground reaction forces during walking – as well as at the femoral neck and lumbar spine.

METHODS

Subjects

Healthy post-menopausal women aged 60–70 were recruited through local general practices. They had to be capable of taking up brisk walking, but not already taking regular exercise. Subjects on hormone replacement therapy were excluded, as were those taking any other prescribed medication or known to have a condition thought to influence bone metabolism. Women with blood pressure over 160/95 mmHg, known cardiovascular disease or ECG abnormalities were also excluded for safety during exercise testing. Eighty-four women met the above criteria and were invited to participate. Subjects gave written informed consent for all procedures. The protocol was approved by Loughborough University's Ethics Advisory Committee.

Study design

Women were randomly assigned to control or walking groups after baseline testing. Subjects in the control group were given the option of attending up to two 20-min sessions per week of swimming, an activity thought to have little influence on bone [13]. In all other respects, control subjects were requested to maintain their habitual physical activity patterns. All subjects were requested not to make any planned changes to their usual diet. Measurements were repeated after 12 months.

Bone mineral density

BMD was measured at the lumbar spine (L2–L4), femoral neck and calcaneus [14] using dual energy X-ray absorptiometry (DXA) on a DPX-L whole-body densitometer (Lunar Corporation, Madison, WI, U.S.A.). The femoral neck site was chosen because of its clinical relevance and better reproducibility than Ward's triangle and trochanter. Standard errors of measurement (standard deviation of differences, divided by $\sqrt{2}$, in 10 women) at lumbar spine, femoral neck and calcaneus were 0.014, 0.017 and 0.016 g/cm² respectively; coefficients of variation (SE expressed as percentage of mean BMD) were 1.4%, 1.9% and 2.7% respectively. Investigators analysing DXA scans were blind to subjects' group assignment.

Broadband ultrasonic attenuation

BUA was measured at the calcaneus using a CUBA research system (McCue Ultrasonics,

Winchester, U.K.) [14]. The SE of measurement was 3.2 dB/MHz (coefficient of variation 5.4%).

Functional capacity

Functional capacity was estimated in order to provide evidence of physiological adaptation and, by inference, compliance with the walking prescription. Maximum oxygen uptake was predicted from the relationship between heart rate (ECG) and oxygen uptake (Douglas bag techniques) [15], during a submaximal, incremental treadmill walking test, the final stage of which elicited approximately 70% of each woman's baseline maximal oxygen uptake.

Habitual physical activity levels

Level of physical activity on joining the study was assessed by questionnaire [16] and expressed as minutes of weight-bearing exercise per day.

Dietary intakes

Dietary intakes of energy and calcium were evaluated by means of 7-day weighed food inventories with subsequent analysis using a computerized version of food composition tables (Compeat 4.1, Nutrition Systems, London, U.K.).

Brisk walking

Walking was at a self-selected 'brisk' pace and had to be in addition to any walking or other physical activity routinely undertaken before the study. The time taken for each subject to walk 1600 m on a flat course was recorded at baseline and used to derive a measure of brisk walking speed. Duration of exercise was prescribed by means of 2-weekly targets, which increased from 120 to 280 min over the first 3 months and remained at 280 min thereafter (Fig. 1). Each walk had to be contin-

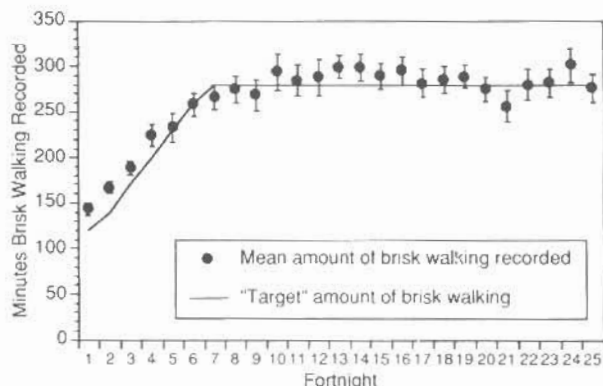


Fig. 1. Mean amount of walking completed every 2 weeks relative to target set: mean (SEM)

uous and 20–50 min long. Subjects completed a training diary recording the number of minutes of brisk walking completed each day, and this was returned to the university monthly. For the most part, subjects undertook their brisk walking at their own convenience and without supervision, but some sessions were held at the university so that heart rate could be recorded using short-range telemetry (Sport Tester, Polar Electro, Kempele, Finland).

Statistical analyses

Changes over the year were calculated and compared between groups using unpaired *t*-tests. Analysis of covariance was used to allow for changes in body mass. Multiple regression analysis was used to examine factors that might have influenced the responses to exercise, using 12-month values as the dependent variable and baseline values with other factors as independent variables.

RESULTS

Seventy-nine women completed the study: 39 walkers and 40 control subjects. Reasons for drop-outs were as follows: two subjects (one walker, one control subject) had surgery; two (both walkers) experienced illness/bereavement in family; and one walker had a fall at home. In addition, data for one walker subsequently found to have hyperthyroidism were excluded. There were no significant differences between control subjects and walkers at baseline in any of the variables studied (Table 1). Eight subjects (four walkers, four control subjects) smoked cigarettes: 12.1 ± 4.3 per day (mean \pm SD). Nine women in the control group opted to take up swimming. These women had significantly lower maximum oxygen uptake values at baseline than the other 31 control subjects (21.8 ± 2.2 ml min⁻¹ kg⁻¹ versus 25.5 ± 4.1 ml min⁻¹ kg⁻¹ respectively; $P = 0.01$). No other variable differed significantly between control subjects who swam and those who did not swim.

Walkers completed, on average, 14.8 ± 3.0 min/day of brisk walking during the first 3 months and 20.4 ± 3.8 min/day subsequently, during an

Table 1. Characteristics of subjects at baseline (means \pm SD). No significance differences between groups.

| | Control subjects (n = 40) | Walkers (n = 38) |
|--|------------------------------|---------------------|
| Age (years) | 64.2 \pm 3.1 | 64.9 \pm 3.0 |
| Years post menopause | 14.6 \pm 6.6 | 15.1 \pm 5.5 |
| Body mass (kg) | 67.9 \pm 10.6 | 67.7 \pm 10.9 |
| Stature (m) | 1.629 \pm 0.073 | 1.619 \pm 0.061 |
| Body mass index (kg/m ²) | 25.6 \pm 3.5 | 25.8 \pm 3.8 |
| Maximum oxygen uptake (ml min ⁻¹ kg ⁻¹) | 24.6 \pm 4.1 | 24.6 \pm 5.4 |
| Weight-bearing exercise (min/day) | 36 \pm 30 | 35 \pm 23 |
| BMD, L2–L4 (g/cm ²) | 1.035 \pm 0.199 | 1.044 \pm 0.175 |
| BMD, femoral neck (g/cm ²) | 0.840 \pm 0.112 | 0.843 \pm 0.109 |
| BMD, calcaneus (g/cm ²) | 0.528 \pm 0.108 | 0.499 \pm 0.093 |
| BUA, calcaneus (dB/MHz) | 64.5 \pm 14.5 | 62.8 \pm 13.6 |

average of 3.5 ± 0.8 , rising to 4.8 ± 1.0 , walks per week. Their brisk walking speed at baseline averaged 1.60 ± 0.1 m/s (3.6 ± 0.2 m.p.h.). Only two women reported walking-related injuries (minor foot problems). Heart rate during brisk walking averaged 110 ± 9 beats/min; i.e. 71 \pm 6% of the age-predicted maximum. The control subjects who swam averaged 34 \pm 37 min of swimming per week.

Maximum oxygen uptake increased ($P = 0.01$) in both walkers [mean change over 12 months (SEM) $+2.1$ (0.9) ml min⁻¹ kg⁻¹] and control subjects who swam [$+3.1$ (1.5) ml min⁻¹ kg⁻¹], relative to control subjects who did not swim [-1.5 (0.5) ml min⁻¹ kg⁻¹]. The response of the control subjects who swam did not differ from that of other control subjects for any of the other variables studied, so results hereafter are reported for the control group as a whole.

There were no significant changes over the year in either group in average daily calcium intake [control subjects 841 (38) mg versus 853 (43) mg; walkers, 836 (35) mg versus 864 (36) mg] or energy intake [control subjects, 7.4 (0.2) MJ versus 7.6 (0.3) MJ; walkers, 7.2 (0.2) MJ versus 7.5 (0.2) MJ]. Body mass increased significantly in control subjects relative to walkers (Table 2).

BMD in the lumbar spine and both BMD and BUA in the calcaneus fell in control subjects but not in walkers (Table 2 and Fig. 2). The change

Table 2. Changes in body mass, BMD and BUA during a 12-month programme of brisk walking: means (SE). *Significant change within group, $P < 0.01$.

| | Subjects | Walkers | Significance of difference in response between groups | Significance of difference in response between groups (adjusted for changes in body mass) |
|--|-------------------|-------------------|---|---|
| Body mass (kg) | $+0.9$ (0.3)* | -0.1 (0.3) | $P = 0.04$ | — |
| BMD, L2–L4 (g/cm ²) | 0.005 (0.004) | -0.006 (0.004) | $P = 0.08$ | $P = 0.06$ |
| BMD, femoral neck (g/cm ²) | $+0.011$ (0.007) | $+0.016$ (0.006)* | $P = 0.60$ | $P = 0.51$ |
| BMD, calcaneus (g/cm ²) | -0.010 (0.004)* | $+0.001$ (0.004) | $P = 0.04$ | $P = 0.02$ |
| BUA, calcaneus (dB/MHz) | 3.7 (0.8)* | -0.7 (0.8) | $P = 0.01$ | $P < 0.01$ |

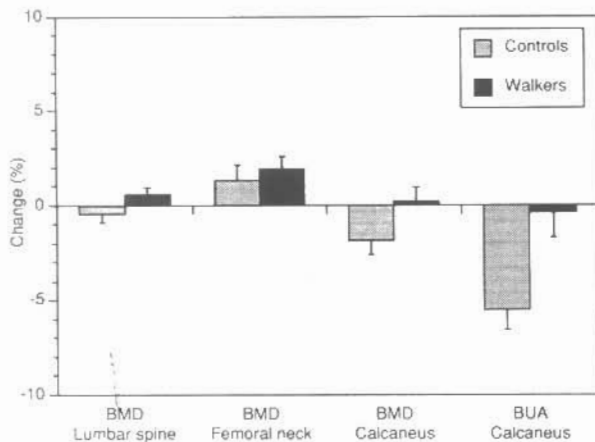


Fig. 2. Changes (%) in BMD and BUA resulting from a brisk walking programme: means (SE)

observed in walkers differed from that in control subjects in the calcaneus (BMD, $P = 0.04$; BUA, $P = 0.01$) but not in the lumbar spine ($P = 0.08$). Femoral neck BMD increased significantly in walkers, although there was also a non-significant increase in control subjects (Table 2). Adjustment for changes in body mass somewhat enhanced the significance of differences in response between groups (Table 2). The average daily duration of brisk walking completed by walkers was related to the change in BMD at the femoral neck (Fig. 3). This relationship remained significant after exclusion of the outlying point evident in Fig. 3 (38 min/day). Duration of walking was not significantly related to change in BMD in the lumbar spine or calcaneus.

DISCUSSION

The new finding of this study was that bone loss was reduced in post-menopausal women by brisk walking – largely unsupervised and practised in a

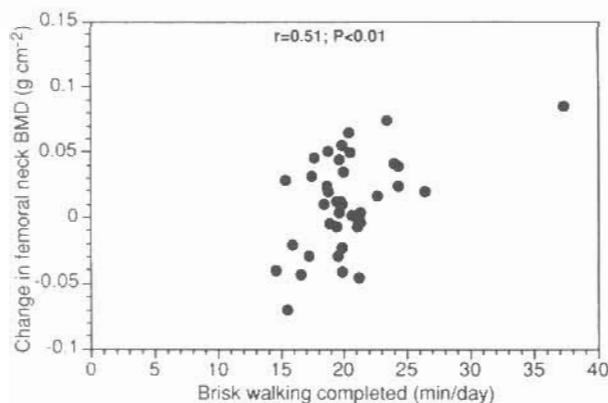


Fig. 3. Relationship between change in BMD in the femoral neck and amount of brisk walking completed

flexible and self-governed manner. Its effect was most pronounced in the calcaneus, where significant reductions in BMD and BUA (of 2% and 5% respectively) occurred in controls but not in walkers. As the calcaneus is the site of heel strike during walking, this conforms to the principle that mechanical strain stimulates a local response to local loading [17]. Changes at sites where forces associated with walking are expected to be lower, the neck of femur and lumbar spine, were smaller, but there were nevertheless indications of a benefit from walking: lumbar spine BMD decreased over the year in controls (-0.5%) but not in walkers ($+0.6\%$); and the amount of walking done was correlated with the change in femoral neck BMD, which could indicate a dose–response relationship.

The changes in lumbar spine BMD seen are similar in magnitude to those reported in post-menopausal women after previous studies of fast/treadmill walking [10, 11], but slightly more modest than those reported after a programme of resistance training [18], which involves greater skeletal loading. This supports animal studies which show that change in bone mass is dependent upon strain magnitude [19], whereas increasing the number of load cycles above a threshold level (approximately 36 cycles per day in avian bone) is a less effective osteogenic stimulus [20]. The major effect of brisk walking on bone loading is probably an increase in the number of load cycles: our walkers typically experienced 60–75 heel strikes per minute when brisk walking (i.e. 1200–1500 load cycles daily during a 20-min bout). There was probably also some increase in strain magnitude, due to increased walking speed. In addition, walking outside, particularly on uneven terrain, may have caused occasional brief exposures to much higher strains.

BUA, which has been reported to be as good a discriminator of patients with hip fracture as DXA measurement at the hip [21], was maintained in walkers relative to control subjects, whose values decreased by 5.5%. These findings confirm our earlier finding, in mainly premenopausal women, [8], that BUA can detect changes in bone provoked by taking up brisk walking. They also add the new information that mean changes in BUA are consistent with mean changes in BMD.

It is difficult to infer what effect taking up brisk walking might have on future fracture risk. Estimates suggest that a reduction in BMD of 1 SD is associated with a two- to threefold increase in fracture risk at the site measured [22]. The reductions in BMD prevented by regular brisk walking over 1 year were of the order of 10% of a SD. This might, in itself, confer only a modest reduction in fracture risk. Available evidence cannot show whether or not continuing over years with this amount of brisk walking would further enhance its effects. In a cross-sectional study, however, walking for exercise has been associated with reduced risk of hip fracture even after allowing for BMD [5].

showing that other factors may be involved. For example, walking may also improve balance in older women [23, 24], further lowering their fracture risk by decreasing the risk of falling.

Changes in body mass over the year may have influenced BMD. Body mass is positively correlated with BMD in cross-sectional studies [25], and weight loss provokes demineralization [26]. In the present study, walkers did not experience the increase in body mass observed in control subjects whose increase in mass could have attenuated their loss of bone over the year. This increase in mass in control subjects could explain why their femoral neck BMD did not fall significantly over the year. Adjusting for weight changes strengthened our findings: the difference between groups in the change in BMD at L2-L4 approached significance ($P = 0.06$). We have, however, chosen to present a main analysis that does not attempt to control for weight changes. Our findings therefore represent the 'real-life' response of bone to taking up brisk walking, recognizing that the avoidance of weight gain by walkers was a consequence of the intervention – and one that probably offset the beneficial effects of the increased levels of mechanical loading due to the walking.

A major limitation of many previous exercise intervention studies is that subjects have not been representative of the population [27]. In our study, mean BMD values in the lumbar spine and femoral neck were 104% of normative, age-matched values. In addition, mean body mass index, functional capacity values and physical activity levels were all close to those reported previously for British women of similar age [28, 29]. Only smoking habits (fewer than 10% were smokers) and calcium intake (nearly 100 mg/day higher than population estimates [28]) could be described as atypical. As post-menopausal women averaging calcium intakes of 750 mg/day showed reduced bone loss with supplementation [30], some of our walkers may have had suboptimal intakes, which may have limited their response.

In summary, our findings reveal a beneficial effect of brisk walking on bone in older women, with reduced bone loss relative to control subjects. Functional capacity was also improved – by an amount sufficient, for example, to increase comfortable walking speed by nearly 0.5 m.p.h. Walking might thus help to break into a debilitating spiral – inactivity, loss of functional capacity, heightened inactivity – which predisposes to accelerated bone loss. Walking is inexpensive, potentially sociable, associated with low injury rates and demonstrably acceptable to women potentially at risk. It typifies dynamic, aerobic exercise with the health benefits associated with this [31]. For all these reasons, brisk walking is eminently suited to promotion in primary care and, as the effects of exercise and oestrogen therapy are reported to be additive [32], could form part of a multifactorial approach to reducing the incidence of osteoporosis.

ACKNOWLEDGMENTS

This research was funded by the Arthritis and Rheumatism Council grant J0048. We are grateful to Dr David Pye, Mandy Blaze, Catherine Wright and Rachel Vincent (Department of Medical Physics, Queen's Medical Centre, Nottingham) for carrying out BMD measurements, Dr Ikiko Tsuritani (visiting researcher, Department of Human Sciences, Loughborough University) for assistance with data collection and analysis, Dr Carol Jagger (Department of Epidemiology and Public Health, University of Leicester) for statistical advice and Professor Jerry Morris (London School of Hygiene and Tropical Medicine) and Dr Tom Robinson (Glenfield Hospital, Leicester) for critical comment on the manuscript.

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