# PAPERS AND SHORT REPORTS

# Effect of two randomised exercise programmes on bone mass of healthy postmenopausal women

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## Abstract

**The effect of two structured exercise programmes on the bone mass of 48 healthy postmenopausal white women aged 50-62 was studied after one year. Volunteers were randomised to group 1 (control), group 2 (aerobic exercise), or group 3 (aerobic and strengthening exercises). Before and after the training programme each subject had evaluations of bone mass (determined by neutron activation analysis and expressed as calcium bone index) and maximum oxygen uptake attained on a multistage exercise treadmill test.**

**After one year both exercise groups had higher levels of fitness and greater bone mass than controls. Mean values (2 SEM) for changes in the calcium bone index were −0·011 (0·037), 0·039 (0·035), and 0·066 (0·036) for groups 1, 2, and 3, respectively. Analysis of variance on the observed data and analysis of covariance adjusting changes to the initial mean value for the whole group showed significant differences between each exercise group and the controls but no difference between the exercise groups themselves. Both exercise groups showed a significant improvement in maximum oxygen uptake.**

**This study suggests that exercise may modify bone loss in healthy postmenopausal women.**

## Introduction

Osteoporosis is a common crippling bone disease affecting mainly postmenopausal white women. It is a multifactorial condition associated with loss of bone to a level at which it is at risk of fracture.[1] Mechanical forces have been implicated as a contributing factor affecting bone homoeostasis.[2]

Changes in bone mass have been found to be related to physical activity. Immobilisation from prolonged bed rest or lack of activity is known to be associated with reduction in bone mineral content.[3] Physical activity, on the other hand, may have a positive effect on bone mass. Studies have shown that exercise may prevent bone loss in postmenopausal women as well as in women with osteoporosis.[4-6] Nevertheless, the benefits of long term intensive physical activity on bone mass remain unclear.[7] Some studies have shown that athletes and people who are engaged in lifelong physical labour have higher bone density.[8-10] Drinkwater *et al*, however, found that young athletes with amenorrhoea had low vertebral bone density.[11] Many unanswered questions remain about the types of physical activity and optimal amount of exercise needed to prevent bone loss.

We report a randomised study evaluating the effect of two controlled structured exercises for healthy postmenopausal women. The study determined (*a*) the subjects' compliance, (*b*) the complications of exercise, and (*c*) the magnitude and variation of bone mass changes measured by neutron activation analysis.

## Subjects and methods

Subjects eligible for the study were healthy postmenopausal white women who had no history of fractures; metabolic bone disease; renal, liver, or thyroid disorders; gastrectomy; alcoholism; or of taking oestrogen or other drugs that might affect bone metabolism. Sixty eight eligible volunteers aged 50-62 were recruited from an advertisement in a local newspaper. They were either housewives or white collar workers. Their average dietary calcium intake was 0·5-1·0 g daily.

After the subjects had given written, informed consent their histories were taken and they were given a physical examination. All had a normal blood count; normal fasting blood glucose and serum calcium, phosphorus, total protein, and electrolyte concentrations; normal liver function; and normal results on urine analysis.

### MEASUREMENTS

Bone mass was measured before and after the study by neutron activation analysis; aerobic capacity was determined by an exercise treadmill test. These tests were performed blind and completed within six weeks before the study and within eight weeks after termination of the study at one year. The mean interval between the two sets of measurements was 14·0 (SEM 0·39) months.

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Neutron activation analysis was carried out as described[12] and measured total calcium in the trunk and upper thighs. These areas contain a high proportion of trabecular bone, which is most at risk of osteoporotic fractures. After exposure to neutron flux from plutonium and beryllium sources the stable isotope calcium-48 was converted in part to radioisotope calcium-49. In the process of decay 3·1 MeV $\gamma$ ray was emitted and measured in a total body counter. The result is expressed as the calcium bone index, which relates an individual value to the mean value for normal people of the same body size, based on maximum height and arm span. Reproducibility of the method is within 5%.

TABLE I—*Individual characteristics of 10 subjects not entered in study and 10 subjects who left study (drop outs) and mean (SEM) values in study groups, including calcium bone index and maximum oxygen uptake in groups 1, 2, and 3 initially and after one year*

| | Age (years) | Years postmenopausal | Weight (kg) | Height (cm) | Calcium bone index | | Maximum oxygen uptake (ml/kg/min) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Initially | After one year | Initially | After one year |
| Subjects excluded from study: | | | | | | | | |
| 1 | 53 | 3 | 83 | 164 | 0·60 | | 23·3 | |
| 2 | 54 | 5 | 58 | 163 | 0·75 | | 28·8 | |
| 3 | 55 | 5 | 67 | 168 | 0·72 | | 28·8 | |
| 4 | 56 | 6 | 56 | 156 | 0·70 | | 23·3 | |
| 5 | 58 | 10 | 53 | 163 | 0·74 | | 28·8 | |
| 6 | 58 | 9 | 77 | 160 | 0·69 | | 23·3 | |
| 7 | 60 | 10 | 82 | 171 | 0·60 | | 23·3 | |
| 8 | 60 | 11 | 61 | 160 | 0·63 | | 23·3 | |
| 9 | 62 | 12 | 82 | 169 | 0·60 | | 15·0 | |
| 10 | 62 | 13 | 56 | 162 | 0·69 | | 23·3 | |
| Drop outs: | | | | | | | | |
| 11 | 50 | 10 | 68 | 163 | 0·82 | | 28·8 | |
| 12 | 51 | 11 | 60 | 165 | 1·04 | | 40·0 | |
| 13 | 51 | 12 | 56 | 158 | 1·18 | | 40·0 | |
| 14 | 53 | 13 | 62 | 167 | 0·82 | | 33·5 | |
| 15 | 54 | 15 | 75 | 167 | 0·66 | | 28·8 | |
| 16 | 54 | 14 | 56 | 165 | 0·73 | | 28·8 | |
| 17 | 58 | 18 | 51 | 158 | 0·88 | | 40·0 | |
| 18 | 58 | 18 | 47 | 155 | 1·01 | | 52·0 | |
| 19 | 60 | 10 | 64 | 162 | 0·99 | | 33·5 | |
| 20 | 62 | 14 | 78 | 156 | 0·86 | | 28·8 | |
| Group 1 (n=15) | 56·33 (0·85) | 8·39 (1·68) | 56·47 (2·44) | 158·87 (6·58) | 0·92 (0·04) | 0·91 (0·03) | 33·17 (2·03) | 33·17 (1·81) |
| Group 2 (n=17) | 56·69 (0·83) | 6·31 (0·99) | 62·29 (2·85) | 159·01 (8·34) | 0·95 (0·02) | 0·99 (0·03) | 32·09 (1·41) | 40·03* (1·70) |
| Group 3 (n=16) | 55·77 (1·02) | 6·91 (1·29) | 60·88 (3·26) | 158·38 (6·27) | 0·88 (0·03) | 0·95 (0·03) | 31·00 (2·65) | 40·95* (2·35) |

Significance of difference from initial value (paired *t* test) $p<0·001$.

Aerobic capacity was determined by maximum exercise testing on a treadmill. Each subject performed a graded exercise test. Subjects walked at zero gradient for three minutes at 4·8 km/h, the treadmill gradient then being raised 4% for each successive three minutes of walking until they could no longer continue. Heart rate, blood pressure, and a 12 lead electrocardiogram were recorded at rest, at the end of each three minute stage of exercise, and every three minutes in the postexercise period. The maximum workload achieved corresponded to the highest three minute stage at which the subject had performed for at least two minutes and reached a steady state. Maximum oxygen uptake, a measure of aerobic capacity, was calculated from the maximum workload by using the conversion formula of the American College of Sports Medicine.[13] This method allows an estimation of oxygen uptake which falls within 10% of values obtained by direct methods.[14]

## RANDOMISATION

After the initial bone mass measurements 10 women with a low calcium bone index (≤0·75) opted for medical treatment and were excluded from the study. The remaining 58 subjects were randomly assigned to one of the following three groups: group 1 (control, n=19); group 2 (aerobic exercise, n=19); group 3 (aerobic plus strengthening exercises, n=20). Randomisation was by opening sealed envelopes supplied in sequence by the coordinator (RC) of the study and prepared from random number tables. All subjects continued with their usual diets and avoided taking medicines containing calcium, vitamin D, or oestrogen throughout. Controls were asked to continue their daily routine activities and to refrain from any regular fitness exercises. They were contacted by telephone about four times during the study year. Women in groups 2 and 3 were enrolled in the exercise classes held in the hospital gymnasium three times a week for one year. The exercises were conducted by a certified exercise fitness leader and supervised by RC.

## EXERCISE PROTOCOL

The aerobic exercise consisted of 5-10 minutes of stretching and callisthenic warm up exercises followed by 30 minutes of aerobic activities, which consisted of walking, jogging, and various dance routines choreographed to music. To ensure that the subject achieved the training heart rate (80% of the functional maximum heart rate recorded during the graded exercise treadmill test) pulses were taken every 10 minutes during the 30 minutes of aerobics. In addition to the aerobic exercise subjects in group 3 had an extra 10-15 minute session of low intensity strength training. This consisted of isometric and isotonic contractions of the various muscle groups in the limbs and trunk, using free weights attached to wrists and ankles. Subjects performed 10 repetitions for each muscle group at 10 repetition maximum (maximum resistance or weight which the muscle can lift through range of motion 10 times).

## COMPLIANCE AND FOLLOW UP

Of the 58 women assigned to the study groups, 48 (83%) completed the repeat measurements at one year. Four of the controls refused the follow up tests; two women in group 2 left the study because of lack of time (one) or pain and swelling in the knee as a result of the exercise (one); and four in group 3 left the study because of knee pain (two) or back pain (one) aggravated by the exercises or lack of interest (one). Thus there were 15 women in group 1, 17 in group 2, and 16 in group 3 who completed the study. The overall average attendance at the exercise classes during the year was 70%.

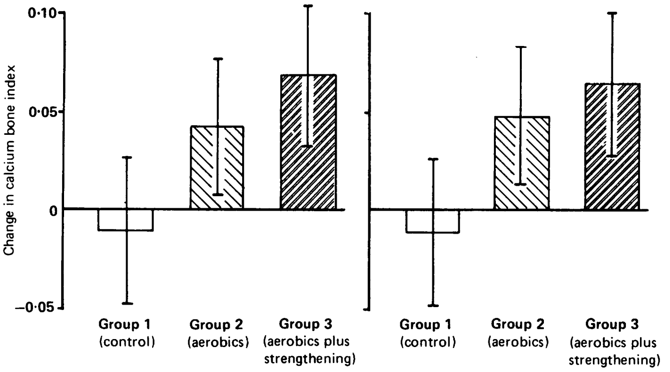
## SAMPLE SIZE AND STATISTICAL ANALYSIS

The standard deviation of the difference between two measurements of calcium bone index was 0·05. By setting alpha at 0·05 (type I error) and beta at 0·20 (type II error) and assuming a normal distribution we calculated that for testing the significance of the mean difference between two samples we should need 15 subjects in each group.[15]

Analysis of variance on observed calcium bone index data was used to compare the three groups. As changes in bone mass depend on initial calcium bone index values, adjusting for prescores was investigated by using analysis of covariance.[15] Pearson's coefficient of correlation was used to determine the relation between changes in calcium bone index and changes in maximum oxygen uptake.

## Results

Table I gives the details of the three groups of women who completed the study and also lists the individual characteristics of the 20 women who either were excluded from the study initially or dropped out before its completion. The initial mean values of bone mass and aerobic capacity of subjects in the three groups who completed the study were within the normal ranges (table I). After one year of training both exercise groups showed a significant increase (p<0·001) in aerobic capacity (table I). Mean values (2 SEM) for the changes in bone mass (calcium bone index) were −0·011 (0·037), 0·039 (0·035), and 0·066 (0·036) for groups 1, 2, and 3, respectively. By analysis of variance on the observed data the increase in calcium bone index for group 3 compared with the controls was significant at p=0·005 and for group 2 significant only at p=0·058 (figure).



Mean values for changes in calcium bone index in the three study groups. Error bars are 2 SEM and give roughly 95% confidence intervals.

*Left* (analysis of variance on observed data)—Difference from control group: group 2 p=0·058, group 3 p=0·005. Difference between groups 2 and 3 not significant (p=0·28). *Right* (analysis of covariance adjusting changes to initial mean value for whole group)—Difference from control group: group 2 p=0·038, group 3 p=0·008. Difference between groups 2 and 3 not significant (p=0·51).

Table II shows the analysis of covariance when adjusting for prescores. The adjusted mean values (2 SEM) for changes in calcium bone index were −0·011 (0·037), 0·044 (0·035), and 0·061 (0·036) for groups 1, 2, and 3, respectively (figure). There was a significant difference between groups 1 and 2 (p=0·038) and between groups 1 and 3 (p=0·008) and no difference between groups 2 and 3 (p=0·51). (If we reject the hypothesis that there was no difference between the two treatment groups and the control group the type I error rate (the chance that one or more of the treatments does not work) based on Bonferroni inequality[16] would be estimated as 0·0375+0·0083=0·0458.)

The correlation coefficient between changes in calcium bone index and changes in maximum oxygen uptake in the 48 subjects was significant (r=0·44; p<0·01).

## Discussion

Mechanical factors that affect bone remodelling include muscular contraction and gravity. Lanyon found that bone responds in proportion to the amount of stress placed on it.[2] Abramson and Delagi showed that weight bearing and muscle contractions generate stress on bone necessary to prevent bone loss.[17]

The relation between physical activity and bone mass has been studied by various investigators. Sinaki *et al* found a significant positive correlation between bone mineral density of the lumbar vertebrae measured by dual photon absorptiometry and back extensor strength.[18] Other studies have shown a significant positive correlation between bone mass of the axial skeleton (determined by either neutron activation analysis or dual photometry) and aerobic capacity.[19,20] In this study we found a positive correlation between the increase in bone mass (calcium bone index) and improvement in aerobic capacity (maximum oxygen uptake) (r=0·44; p<0·01).

The neutron activation procedure is considered more reliable than the various density measurements.[21] Our neutron activation procedure measures bone mineral directly and includes all the central parts of the skeleton that are most at risk of osteoporotic fracture. These are also weightbearing areas which are subjected to gravitational forces and repetitive muscular actions during conditioning or muscle training exercises. We are therefore encouraged that both this procedure and density measurements on distal forearm[5] and lumbar spine[6,18] have detected a significant improvement in bone mineral mass after exercise.

Exercise has been shown to prevent bone loss in the elderly. Krolner *et al* compared the bone mineral content of the lumbar spine measured by dual photometry in a controlled study of healthy women aged 50-73 who were assigned to either a control or exercise group. The exercise group performed one hour of walking and a range of motion exercises twice a week for eight months. The bone

TABLE II—*Analysis of covariance (SAS Institute* general linear models procedure)*

Dependent variable: difference

| Source | Degrees of freedom | Sum of squares | Mean square | F Value | p>F | Multiple correlation coefficient | Coefficient of variation |
|---|---|---|---|---|---|---|---|
| Model | 3 | 0·06167222 | 0·02055741 | 4·05 | 0·0126 | 0·216206 | 220·7474 |
| Error | 44 | 0·22357570 | 0·00508127 | | | | |
| Corrected total | 47 | 0·28524792 | | | Root mean SE<br>0·07128300 | | Difference, mean<br>0·03229167 |

| Source | Degrees of freedom | Type I sum of squares | F Value | p>F | Degrees of freedom | Type III sum of squares | F Value | p>F |
|---|---|---|---|---|---|---|---|---|
| Treatment | 2 | 0·04772311 | 4·70 | 0·0142 | 2 | 0·04273582 | 4·21 | 0·0213 |
| Prescore | 1 | 0·01394911 | 2·75 | 0·1047 | 1 | 0·01394911 | 2·75 | 0·1470 |

Least squares mean

| Group | Difference (least squares mean) | SE (least squares mean) | p> *t* Distribution. Null hypothesis: least squares mean=0 | p> *t* Distribution. Groups 1, 2, 3/ comparing groups | Null hypothesis: least squares mean (groups 1, 2, 3)=null hypothesis: least squares mean (comparing groups) | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 |
| 1 | −0·01083356 | 0·01840766 | 0·5592 | 1 | | 0·0375 | 0·0083 |
| 2 | 0·04360557 | 0·01752792 | 0·0167 | 2 | 0·0375 | | 0·5078 |
| 3 | 0·06070054 | 0·01813277 | 0·0017 | 3 | 0·0083 | 0·5078 | |

*SAS Institute Inc, Cary NC 27511, USA, PO Box 8000. (*SAS User's Guide*, *SAS Manual*.)

mineral content of the lumbar spine increased by 3·5% in the exercise group, whereas in the controls it decreased by 2·7%.[6] Aloia and coworkers studied healthy postmenopausal women (mean age 53) over one year and found an increase in total body calcium (determined by total body neutron activation analysis) in the exercise group, who performed exercises recommended by the President's Council on Physical Fitness[22] three times a week, compared with a control group.

In this study we found a decrease in body calcium in the axial skeleton of controls. Both exercise groups showed a significantly increased bone mass compared with controls. In addition, the exercise groups had a significant improvement in maximum oxygen uptake as a training effect after one year. Other studies have also shown an improvement in aerobic endurance with training in women.[23 24] The aerobic exercises consisted of dynamic weight-bearing activities that placed stress on the trunk and lower extremities.

The muscle strengthening exercise in this study was a submaximal training session. Bone mass changes may be affected by weight-bearing aerobic activities and by forces generated by muscle contraction. In our series the supplementary muscle strengthening programme (group 3) had no obvious additive effect on bone mass. We were unable to detect improvements in muscle strength in the exercise groups as most of the women could not tolerate muscle testing using free weights in the bench press and leg press. We are now, however, designing a study to evaluate the effect of a weight training programme on the bone mass of postmenopausal women.

There were several limitations in our study. Firstly, the subjects were volunteers who responded to a newspaper advertisement. They may have represented a biased sample of self motivated and health conscious people and therefore may not have been truly representative of the general population. Secondly, the neutron activation analysis has a reproducibility error of 5% and the normal calcium bone index ranges from 0·75 to 1·2. As changes in the calcium bone index depend on initial values, conceivably subjects who began the study with a comparatively low calcium bone index (<0·9) would have had greater potential to show a significant increase in bone mass if exercise did indeed have a beneficial effect. With higher calcium bone index values (>0·05—for example, those in group 2) the possible range for increase is considerably narrower. Ideally, the study should have been carried out in women with low normal or subnormal calcium bone index values. It would be difficult to get a large enough sample, however, as most healthy early postmenopausal women have higher calcium bone index values. Lastly, it was difficult to control for other confounding variables or cointervention, especially in the controls. Though all the subjects adhered to their regular (North American) diet with an average intake of 0·5-1·0 g calcium daily, they were not willing to change lifelong habits such as caffeine intake, alcohol consumption, or cigarette smoking, any of which might affect bone homoeostasis.[25 26] Similarly, it would be unrealistic to expect subjects in the control group to refrain from physical activities or regular exercises on their own.

We conclude that postmenopausal bone loss can be prevented by exercise. In this study both exercise groups showed a significant increase in bone mass and aerobic capacity after one year of training as compared with controls. The therapeutic efficacy of muscle strengthening plus aerobic exercises was not significantly different from that of aerobic exercise alone.

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