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Good Maintenance of High-Impact Activity-Induced Bone Gain by Voluntary, Unsupervised Exercises: An 8-Month Follow-up of a Randomized Controlled Trial

ARI HEINONEN, PEKKA KANNUS. HARRI SIEVÄNEN, MATTI PASANEN, PEKKA OJA. and ILKKA VUORI

ABSTRACT

The purpose of this study was to evaluate whether premenopausal women's voluntary unsupervised aerobic and step training could maintain the skeletal benefits obtained by an l8-month supervised high-impact training, and if so, to what extent. Thirty women of the original 39 study subjects (i.e., persons who completed the preceding H-month randomized training intervention and who volunteered to continue the training on their own for a further 8 months) and 19 women of the 45 original control subjects (i.e., persons who volunteered to continue as controls) were included. The study group trained an average of twice per week and the training consisted of regular aerobic and step classes provided by local fitness centers. Areal bone mineral density (BMD, g/cm^2) was measured from the lumbar spine, femoral neck, trochanter area of the femur, distal femur, patella, proximal tibia, calcaneus, and dominant distal radius at baseline and after 18 and 26 months. During the extended 8-month follow-up, the BMD of the study group increased more at the femoral neck (the intergroup change was +0.9% at 18 months and +2.8% at 26 months,p = 0.004 for the change between 18 and 26 months) and remained at the 18-month level at the distal femur, patella, proximal tibia, and calcaneus. In these sites, the statistically significant changes during the entire 26 months of training were 1.7-4.0% in the training groups compared with the changes of -0.9-1.5% in the control group. In the lumbar spine, BMD decreased from the 18-month level in both groups. In conclusion, the significant BMD increases that were obtained by supervised 18-month high-impact training were effectively maintained with subsequent unsupervised regular aerobic and step classes (twice per week). The finding emphasizes the effectiveness and feasibility of self-controlled aerobic and step exercises in the primary prevention of osteoporosis among healthy premenopausal women. (J Bone Miner Res 1999;14:125-128)

INTRODUCTION

OSTEOPOROSIS IS an Increasing health care concern as populations age all over the world The social and economic burden of osteoporosis is due to its clinical outcome of fractures. which Increase in frequency exponentially with age.[1] In the pathogenesis of osteoporotic fractures, age-related bone loss plays an Important role, and. therefore. studies with exercise. calcium. vitamin D, estrogens. bisphosphonates. and other agents have been directed toward improvements or maintenance in bone mass and density. In conjunctlon with the risk factors for falling. bone mineral density (BMD) is one of the most Important determmants of fracture risk. accounting for 80-90% of the variance in the strength of the proximal femur.[2]

There is little doubt that exercise is beneficial to rhe skeleton.[3–8] Of different exercise modalities, the high-impact activity seems most osteogenic.(5) Evidence for this is provided by recent prospective follow-up studies of athletes(4,8) and controlled clinical trials of nonathletes.(6,7) Our recent randomized study,[6] which applied an l&month high-impact exercise regimen for premenopausal women. showed significant BMD increases (1.4-3.7%) at the lumbar spine and several lower limb sites. The regimen consisted of aerobic jumping and srep exercises with a rapidly rising force profile. in which the magnitude of the ground

UKK Institute for Health Promotion Research. l-ampere. Finland.

TABLF 1 ADJUSTED AREAL BMD INTERGROUP DIFFERENCES AT 18 AND 26 MONTHS (MEANS AND THEIR 95% CONFIDENCE INTERVALS [CIs])

Skeletal site	18 months ΔBMD g/cm2 (95% CI)	Δ%	26 months ΔBMD g/cm² (95% CI)	Δ%
Lumbar spine	0.013 (-0.003 to 0.029)	1.3	0.008 (-0.010 to 0.026)	0.8
Trochanter	0.003 (-0.010 to 0.016)	0.3	-0.001 (-0.013 to 0.015)	01
Femoral neck	0.010 (-0.003 to 0.024)	0.9	0.026 (0.011 to 0.040)	2.8
Distal femur	0.024 (0.010 to 0.038)	1.9	0.028 (0.017 to 0.039)	2.3:
Patella	0.011 (0.003 to 0.020)	1.0	0.013 (0.004 to 0.022)	12
Proximal tibia	0.029 (0.018 to 0.04 1)	2.7	0.035 (0.022 to 0.047)	3.2
Calcaneus	0.011 (0.002 to 0.020)	1.9	0.016 (0.007 to 0.025)	2.5
Distal radius	-0.001 (-0.008 to 0.007)	-0.3	0.001 (-0.007 to 0.009)	0.3

Thr post-training difference between training (n = 30) and control (n = 19) groups was adjusled for the haseline values.

reaction forces were gradually Increased by increasing the jumping height However. an important question remained of whether the obtained bone benefits could be maintained after the supervised training program by voluntary, less-demanding exercises; previous studies indicate that BMD decreases after cessation of training.(9,10)

The purpose of this study was, therefore, to evaluate whether subsequent unsupervised regular aerobic and step training could mamtain the high-impact activity-induced skeletal benefits and, if so. to what extent.

MATERIALS AND METHODS

Orrginally, 84 sedentary, healthy, normally menstruating premenopausal women 35-45 years of age completed an I8-month randomized controlled exercise intervention."' In the current 8-month follow-up extension, 30 of the original 39 trainees (39 [2. SD] years, 164 [1) cm, 61 [7] kg at the start of the original study) continued unsupervised training for a further 8 months. and 19 out of the 45 control subjects (38 [3] years. 164 [1] cm. 61 [5] kg) continued as controls. The remaining 9 study subjects and 26 control subjects who could not attend the final 26-month check-up point did not differ from those who participated in the follow-up with regard to the baseline subject characteristics and the 18-month training effects (training subjects). Reasons for withdrawal were Increased occupational or home responsibilities or loss of interest.

Areal BMD (g/cm') measurements were done at baseline. after 18 months. and after 26 months at the lumbar spine. femoral neck, trochanter area of the femur, distal femur, patella, proximal tibia, calcaneus, and dominant distal radius using dual-energy X-ray absorptiometry (XR-26: Norland Corp., Fort Atkinson, WI. U.S.A.).(6) All the scanning and analyses were done by the same experienced operator according to our established procedures."" The coefficient of variation (CV) of the BMD measurement in our laboratory ranged from 0.5–0.8%.(11) Our quality assurance protocol for the scanner(12) indicated no significant machine drift during the study.

In addition, the fitness parameters, I.e.. maximum isometric strength. muscular and cardiovascular performance. dynamic balance. and calcium intake (four occassions of complete 3-day dietary records). were also assessed These measurements were described in detail previously.(6)

The aforementioned 30 women who were able to continue the subsequent 8-month unsupervised training per-rod were asked to train three times per week. The training consisted of regular aerobic and step classes provided by local fitness centers. Each class consisted of about 60 minutes of aerobics or step training, and the target heart rate was 120-160. The step heights were from 10 cm to 15 cm. and the stepping tempo was 122-128 beats/minute. The pilot study revealed that the peak forces varied between 2 and 4.5 times body weight in these regular exerciser: this was somewhat lower loading than produced by the progressive jumping exercises (2.1-5.6 times body weight) of the original super-vised 18-month exercise intervention (6)

In the-statistical analysis. general linear models with the restricted maximum likelihood estimation were used as the method of statistics to assess the Intergroup differences in the BMD changes. (13) The analysis Included the subjects who completed the entire 26-month period

RES ULTS

The 30 study subjects trained on average twice per week. which was slightly less than the 2 5 times per week during the preceding supervised per-rod The 19 controls continued their normal life without exercise training The calcium intake was sufficient in each group being 1026 (326) mg/day at baseline, 1021 (251) mg/day at 18 months. and 1033 (398) mg/day at 26 months in the training group. and 1086 (467) mg/day, 1047 (331) mg/day. and 1047 (270) mg/day in the control group, respectively.

During the 8-month follow-up extension. BMD of the study group continued to increase at the femoral neck (the intergroup change was +0.9% at 18 months and +2.8% at 26 months, p = 0.004 for the change between 18 and 26 months) and was maintained at the 18-month level at the distal femur, patella, proximal tibia. and calcaneus (Table 1). At all these sites, the 26-month changes were statistically

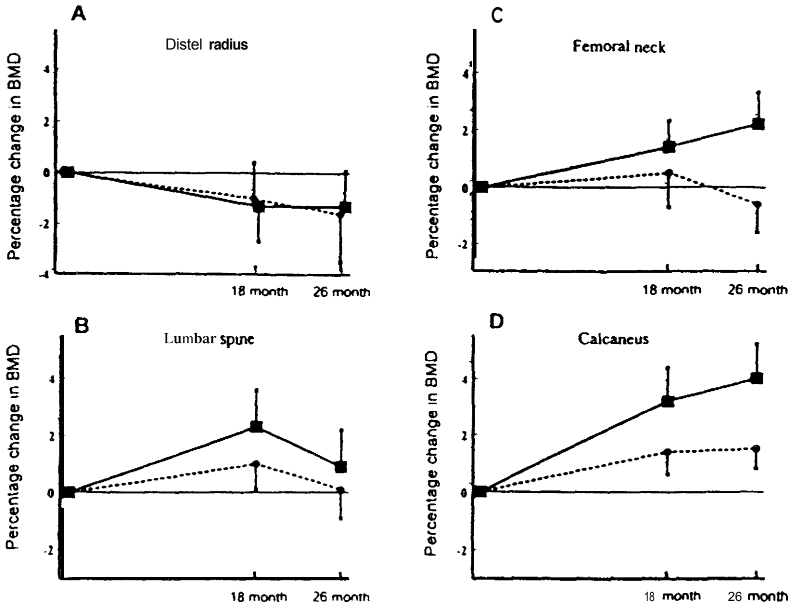

FIG. 1. Percentage change in the BMD at (A) distal radius (= nonloaded site), (B) lumbar spine, (C) femoral neck, and (D) calcaneus during the 18-month supervised training period and subsequent 8-month follow-up with unsupervised training. The solid line represents the training group (n = 30) and the dotted line the control group (n = 19). Bars indicate 95% confidence intervals.

significant, being 1.7-4.0% in the training group and -0.9-1.5% in the control group (Fig. 1). A significant 26-month post-training group difference (in favor of the training group) was seen at the femoral neck (p = 0.001), distal femur ($p < 0.001$). patella (p = 0.005). proximal tibia (p < 0.001). and calcaneus (p = 0.001). There were no significant differences between the groups at the lumbar spine. trochanter area of the femur. and the nonloaded distal radius at 26 months.

The changes in the trainees' fitness parameters ranged from 4% (isometric leg press) to 17% (vertical jump with additional weight of 10% of the body mass) at 18 months and from 1% (isometric leg press) to 9% (vertical jump with additional weight) at 26 months. The controls' corresponding values were from 0% (figure-eight running) to 13% (vertical jump with additional weight) at 18 months and from 0% (isometric leg press) to 8% (vertical jump with additional weight) at 26 months. A significant 18-month post-training group difference was seen in the vertical jump with additional weight (p = 0.008) and figure-eight running test (p = 0.026). At the 26 months, the post-training difference was not significant at any fitness parameter.

DISCUSSION

Exercise has been shown to positively affect BMD at various skeletal sites, and to be most effective. a relatively vigorous aerobic and strength training seems to be needed[3,6,7,9,14,15] It has been also suggested that to maintain the exercise-induced bone gain. it is necessary to keep the elevated loading level"(16) otherwise, the positive effects of training start to disappear.(9)(10) Our original study showed significant BMD increases at the lumbar spine and several loaded lower limb sites (but not at the nonloaded distal radius) by a high-impact loading regimen.(6) In the present study, the BMD at the most loaded skeletal sites, such as the femoral neck, distal femur, patella, proximal tibia, and calcaneus, continued to increase although the training was done at lower volume and intensity. This suggests that it is possible to maintain the increased bone mass with unsupervised less-demanding aerobic and step classes, an important point in consideration of long-term acceptability and compliance of exercise in adult women.

The limitation of our study was that we had no follow-up data from the training subjects and controls who did not participate in the extended $-month follow-up. It is. however. recalled that these withdrawn subjects did not differ from those who attended the follow-up in terms of baseline subject characteristics or BMD changes during the first 18-month period. and for this reason we believe that our current findings are not biased. The second limitation was that the follow-up time was relatively short to draw any conclusions on long-term BMD changes of the subjects. However. it is reasonable to believe that if the trainees will continue this voluntary training (twice a week). their BMD will not decrease.

Literature provides evidence that relatively vigorous strength training"[7,17] and endurance training('[9,17,18] can add bone mass even to the postmenopausal skeleton. However. high-impact exercise. which has been shown to positively affect younger skeleton. can be too rigorous or even injurious to start at an older age. At this point. we cannot make any positive or negative statement on long-term suitability of high-impact exercise for elderly women, but aerobic and step classes can be easily modified and adjusted depending on the age and skills of the group and may pro vide an effective and safe activity regimen. Because aerobic and step classes are particularly popular among women. this setting implies good feasibility in the general female population.

In conclusion, this study suggests that the high-impact training-induced significant BMD increases among premenopausal women can be effectively maintained with subsequent less-demanding aerobic and step classes. If adopted as a part of lifestyle, this type of voluntary training may offer a valuable tool for primary prevention of osteoporoSIS. Further studies with longer follow-ups (5-10 years) are needed_ however, to develop age-specific exercise programs in increasing or maintaining BMD, reducing the risk of falling. and reducing the incidence of osteoporotic fractures.

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Address reprint requests to:
Ari Hemonen Ph. D.
UK K Institute
P 0. Box 30
FIN-33501 Tampere. Finland

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