Osteoporos Int (2004) 15: 248–251
DOI 10.1007/s00198-003-1559-0

ORIGINAL ARTICLE

Former exercisers of an 18-month intervention display residual aBMD benefits compared with control women 3.5 years post-intervention: a follow-up of a randomized controlled high-impact trial

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Received: 20 March 2003 / Accepted: 29 July 2003 / Published online: 12 December 2003

Abstract Exercise is recommended to enhance bone health but data on the maintenance of the exercise-induced bone benefit is sparse. The purpose of the study was to assess the maintenance of the musculoskeletal benefits obtained in an 18-month intervention of high-impact exercise in premenopausal women (34 former trainees and 31 controls). Physical performance and areal bone mineral density (aBMD, g/cm^2) were measured at baseline, after 18 months, and after 5 years. All significant 18-month improvements relative to controls in the trainees' neuromuscular performance (isometric leg press, and vertical jump with and without additional 10% weight of the body mass) had been lost at the 5-year follow-up. However, since the changes in aBMD in both former trainees and controls by time were similar, the exercise-induced aBMD gain (i.e. the mean statistically significant intergroup differences of 1–3% in favor of the trainees) was maintained at the femoral neck, distal femur, patella, proximal tibia, and calcaneus at the 5-year follow-up. At lumbar spine, the difference was 1.7% at both 18-month and at the 5-year follow-ups but the difference was not statistically significant (NS) in the latter follow-up. At the trochanter and unloaded distal radius, the intergroup aBMD differences were NS at both the 18-month and 5-year follow-ups. In conclusion, the bone sites aBMD increased in response to the 18-month intervention, also demonstrated maintenance of this gain 3.5 years after the intervention. In contrast, the exercise-induced improvements in the neuromuscular performance vanished during the post intervention follow-up. These findings suggest the possibility of long-term bone benefits of high-impact training in women.

Keywords Areal bone mineral density (aBMD) · Detraining · Exercise · Osteoporosis · Prevention

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Introduction

High-impact activity seems most beneficial for a human skeleton [1,2]. However, some studies assessing whether the exercise-induced bone gain could be maintained after cessation of the training have suggested that in pre- and postmenopausal women the training-induced increment in areal bone mineral density (aBMD) may disappear during the period of detraining [3,4,5]. In contrast, retrospective cross-sectional studies on former athletes and their controls have given evidence that at least some residual benefits of exercise can be maintained [6,7,8,9,10,11,12]. Supporting these results, our 4- and 5-year prospective follow-ups of retired adult racquet-sports players have shown good maintenance of the exercise-induced difference in bone mineral content between playing and non-playing arms, despite clearly reduced training and regardless of the starting age of the activity [13,14]. Similarly, the significant aBMD increase obtained by a supervised 18-month high-impact jumping training was effectively maintained during the subsequent 8 months by voluntary step-aerobic classes (approximately twice a week), emphasizing the effectiveness of less regular and less demanding exercises in the maintenance of the jumping-induced bone benefits [15]. However, none of the previous intervention studies has assessed longer-term maintenance of exercise-induced bone gain, the post-intervention period clearly exceeding 1 year.

Materials and methods

Originally, 84 sedentary and healthy premenopausal women 35–45 years of age completed an 18-month randomized controlled exercise intervention [16]. Five-year follow-up measurements (3.5

years after the end of the intervention) were done for 34 (87%) of the 39 trainees [39.6 (SD 2.2) years, 164 (0.1) cm, 61 (7.0) kg at the baseline] and 31 (69%) of the 45 control subjects [38.4 (2.7) years, 165 (0.1) cm, 61 (7.6) kg]. The five former trainees and 14 controls who could not attend the 5-year follow-up did not differ from those who participated with regard to the baseline aBMD and subject characteristics or the aBMD change during the 18-month intervention. Reasons for not attending the 5-year follow-up were that the person had moved away or had no more interest in the study.

Areal bone mineral density (aBMD, g/cm^2) was measured at baseline, after 18 months, and after 5 years at the lumbar spine, femoral neck, trochanter, distal femur, patella, proximal tibia, calcaneus, and dominant distal radius using dual-energy X-ray absorptiometry (XR-26; Norland Corporation, Wisconsin, USA). The scanning and analyses were done according to our established procedures [17]. In vivo precision of the aBMD measurements is about 1% in our laboratory [17]. In addition, our quality assurance protocol indicated no significant scanner drift during the study period [18].

All subjects were carefully interviewed about their diet and other living habits, menstrual status, medication, injuries, diseases, and general physical activity during the follow-up. Height (cm) and weight (kg), and the physical performance tests, i.e. maximum isometric leg extension strength, counter movement jump (first without, and then with an additional weight of 10% of the body weight), and figure-of-8 running (for agility and dynamic balance) were done using the procedure described in detail in the previous paper [16].

General linear models (GLM) with the restricted maximum likelihood estimation were used to assess the intergroup aBMD differences at 18 months and 5 years, the difference being adjusted for the baseline aBMD values [16,19].

Results

The interview revealed no major changes in the subjects' diet or other living habits during the post-training follow-up. Thirty former trainees and 24 controls reported that they had done some kind of brisk physical activity once a week or more, while the remaining four former trainees and seven controls reported being inactive during the follow-up. The types of activities were very similar among the 30 former trainees and 24 controls [walking, pole-walking, cycling (mostly commuting), cross-country skiing, swimming and aqua-aerobics, dancing, and low-resistance weight training-classes]. Only four of these former trainees and five of the controls reported about participation in impact-type of training (step aerobics, aerobics or volleyball) on average twice a week.

There were no severe injuries during the follow-up period, and no one used bone-affecting medication except for one former trainee and two controls, who had started estrogen replacement therapy. Menstrual irregularities were not reported. There were three oral contraceptive users in the former training group and six among the controls at the 5-year follow-up. None of the subjects had given birth during the follow-up. One trainee and one control had had sterilization surgery, and two trainees and one control hysterectomy after the 18-month intervention.

Baseline aBMD values and mean aBMD differences between the groups, with the 95% confidence intervals, at the 18-month and 5-year follow-ups are shown in Table 1. The percentage aBMD changes at the clinically important bone sites, lumbar spine and femoral neck, are given in Fig. 1. The 5-year follow-up measurements revealed similar intergroup aBMD differences, in favour of the trainees, than those seen after the 18-month intervention. At lumbar spine, the adjusted between-group differences were 1.7%, after the intervention, and 1.7% at the 5-year follow-up (NS), at femoral neck (1.2%, and 1.7%, respectively), distal femur (2.2%, 2.9%), patella (0.7%, 1.7%), proximal tibia (3.3%, 3.0%), and calcaneus (1.0%, 1.2%). No intergroup aBMD differences were seen at the trochanter, and non-loaded distal radius (reference site) after the 18-month intervention or at the 5-year follow-up (Table 1).

Table 1 Intergroup aBMD differences at the 18-month and 5-year follow-ups (mean, 95% confidence interval and *P*-value), the difference adjusted for the baseline values

		Baseline aBMD, g/cm^2		Intergroup difference at the 18-month follow-up			Intergroup difference at the 5-year follow-up		
		Mean	SD	Difference	95% CI	*P*-value	Difference	95% CI	*P*-value
Lumbar spine	Trainees (n=34)	1.038	0.154	0.0171	0.003–0.032	0.019	0.017	−0.002–0.035	0.082
	Controls (n=31)	1.002	0.115						
Femoral neck	Trainees	0.889	0.114	0.012	0.001–0.023	0.026	0.017	0.000–0.034	0.045
	Controls	0.850	0.093						
Trochanter	Trainees	0937	0.117	0.005	−0.007–0.016	0.441	0.008	−0.009–0.026	0.354
	Controls	0.895	0.104						
Distal femur	Trainees	1.221	0.121	0.022	0.010–0.033	< 0.001	0.029	0.009–0.049	0.004
	Controls	1.191	0.111						
Patella	Trainees	1.042	0.101	0.007	0.000–0.015	0.053	0.017	0.005–0.030	0.007
	Controls	1.027	0.100						
Proximal tibia	Trainees	1.078	0.112	0.033	0.022–0.044	< 0.001	0.030	0.012–0.048	0.002
	Controls	1.044	0.092						
Calcaneus	Trainees	0.605	0.081	0.010	0.002–0.018	0.012	0.012	0.001–0.023	0.037
	Controls	0.580	0.066						
Distal radius	Trainees	0.372	0.044	−0.001	−0.009–0.006	0.732	−0.011	−0.023–0.001	0.084
	Controls	0.354	0.041						

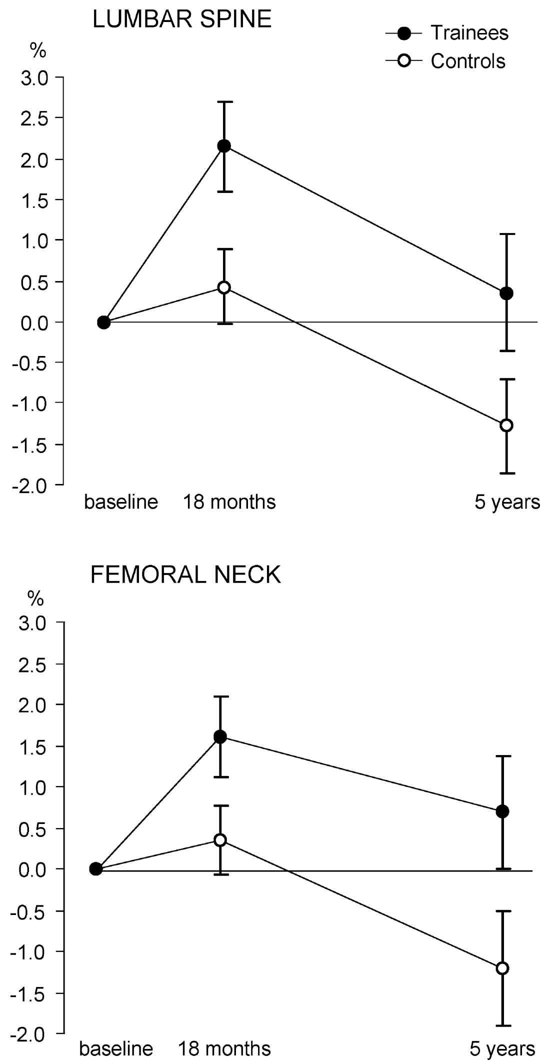

Fig. 1 Percentage aBMD change at the lumbar spine and femoral neck during the 18-month training period and the subsequent 3.5 years of follow-up. *Black circles* represent the training group ($n = 34$) and *open circles* the control group ($n = 31$). *Bars* indicate the standard error of the mean (SEM). Between-group difference is statistically significant ($P < 0.05$) at the lumbar spine at 18-month, and at the femoral neck at 18-month and 5-year follow-ups

A significant 18-month post-intervention group difference, in favour of the trainees, was observed in the leg extension strength (11.9 kg, 95% CI; 4.4–19.3), vertical jump flying time (0.014 s, 95% CI; 0.002–0.027), and vertical jump flying time with an additional weight of 10% of the body weight (0.021 s, 95% CI; 0.007–0.035), while no significant intergroup difference was seen in the figure-of-8 running test (-0.17 s, 95% CI; −0.47–0.13). At the 5-year follow-up, all these intergroup differences had disappeared.

Discussion

It has been suggested that exercise-induced bone benefits start to disappear after cessation of training [3,4,5], particularly if the bone benefit has been obtained after the skeletal maturity [20]. However, in the present study of women in their mid-40s, the training-induced aBMD difference between the former trainees and controls was well maintained for 3.5 years, although the training-induced intergroup differences in physical performance tests were lost at the same period of follow-up. This suggests that the high-impact activity-induced bone benefit can be maintained with ordinary, low-impact type of activities, such as walking, cycling, and low-intensity weight-training classes, an important point when considering the feasibility and long-term utility of training interventions in adult women, but that impact-training induced improvements in neuromuscular performance can be maintained with impact-type (plyometric) training only. Our bone results thus suggest that it is easier to maintain the exercise-induced bone gain than obtain additional minerals through exercise.

The limitation of our study is in its observational nature after the 18-month randomized controlled trial concerning particularly the evaluation of the subjects' physical activities and changes during the follow-up. Although all subjects answered the questions about the type, frequency, intensity, and duration of the activities they were engaged in during the post-intervention follow-up, only a few had performed these activities so regularly that they could give exact answers. On the other hand, in general the post-intervention activity levels were moderate only, and the former trainees and controls had practiced very similar types of low-impact activities after the intervention so that the observed between-group aBMD differences at 5-year follow-up were probably attributable to true maintenance of the 18-month training-induced aBMD gain. In addition, only three former trainees had continued step-aerobic classes throughout the 3.5-year follow-up period and these step-aerobic classes contained mainly stepping on and off step benches without additional impacts from jumps, such as was progressively done during the 18-month intervention [16]. In addition, the disappearance of the between-group difference in the leg extension strength and power during the post-intervention phase speaks strongly for true detraining of the former trainees (with respect to jumping and other high-impact activities) and thus maintenance of the jumping-induced bone gain.

The earlier detraining studies with pre- and postmenopausal women have suggested that the benefits of exercise may become lost after the end of the intervention [3,4,5]. In two of these studies [3,5], however, the number of subjects was rather small and only the lumbar spine aBMD was measured. In a recent study with premenopausal women [4], in turn, the spinal, femoral and total body aBMD changes during the 6-month detraining period were evaluated using a within-subjects design for detrainees and controls separately, which raises the question of whether the interpretation of the results would have been different if the detraining effects had been analyzed similarly to the training effects, i.e. by between groups analysis of covariance. In the present study, both the trainees and controls showed subsequent aBMD loss in most of the measured bone sites, although the intergroup difference (i.e. the exercise-induced aBMD benefit) still existed at these sites at the 5-year follow-up. In order to avoid the age-related aBMD loss, and, to either maintain the aBMD values at the same level as they were after the intervention or increase them, a continuation of impact-type exercise would have been needed. In such a case, it is possible that the aBMD difference between the trainees and controls might have even increased by time.

A fundamental future question is what will happen to these favorable 5-year results when the subjects will enter into menopause, a period of rapid general bone loss. Thus, a further follow-up of our women is warranted. Nevertheless, this study gives promising evidence to encourage women to take part in high-impact type of training, because it seems that women are able to maintain most of the high-impact activity-induced bone gain for years with common physical activities only, making thus strenuous training periods more feasible and motivating.

In conclusion, this follow-up suggests that at sites where high-impact training could induce significant bone gain among premenopausal women, the relative benefit could be maintained at least 3 years after cessation of the impact activity. Further studies with longer follow-ups are, however, needed to confirm these results to evaluate the amount of the activity needed to maintain the benefit, and finally, to assess whether exercise interventions could help in reducing the risk of osteoporotic fracture in older age.

Acknowledgements We thank Mrs. Virpi Koskue, Mrs. Kirsi Mansikkamäki, and Mrs. Ulla Hakala for expert DXA measurements, and Mrs. Taru Helenius for help in the subject recruitment, and Dr. Saila Kauhanen for assistance with the data processing.

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