Long-Term Four-Year Exercise Has a Positive Effect on Menopausal Risk Factors: The Erlangen Fitness Osteoporosis Prevention Study

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LONG-TERM FOUR-YEAR EXERCISE HAS A POSITIVE EFFECT ON MENOPAUSAL RISK FACTORS: THE ERLANGEN FITNESS OSTEOPOROSIS PREVENTION STUDY

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ABSTRACT. Kemmler, W., K. Engelke, S. von Stengel, J. Weineck, D. Lauber, and W.A. Kalender. Long-term four-year exercise has a positive effect on menopausal risk factors: The Erlangen Fitness Osteoporosis Prevention Study study. *J. Strength Cond. Res. 21(1):232–239. 2007.*—The purpose of the study was to determine the effect of long-term exercise on coronary heart disease, osteoporotic risk factors, and physical fitness parameters in postmenopausal women. Forty early postmenopausal women (age 55.1 ± 3.3 years) with no medication or illness affecting bone metabolism exercised (high impact aerobic, multilateral jumps, multi-set resistance exercise) for 50 months (EG), while 28 women (age 55.5 ± 3.0 years) served as a nontraining control (CG). Both groups were supplemented with calcium and cholecalciferol. Bone mineral density (BMD) was measured at the lumbar spine, hip, and forearm by dual energy x-ray absorptiometry. Blood lipids were determined using serum samples, and body composition was determined using the bioimpedance technique. Further, maximum isometric strength was determined (Schnell M3, Schnell Trainer). The BMD at the lumbar spine (+1.0%, $p = 0.037$) and the total hip (−0.3%, $p = 0.194$) were maintained in the EG, while significant ($p < 0.001$) decreases were observed in the CG (lumbar spine −3.2; total hip −2.3%). Differences between both groups were significant ($p < 0.001$). Significant differences between EG and CG were also observed, respectively, for total cholesterol (−6.1 vs. +3.5%, $p = 0.008$), HDL-cholesterol (+14.1 vs. −7.1%, $p = 0.007$), triglycerides (−10.2 vs. +27.5%, $p = 0.002$), body fat (−3.3 vs. +1.3%, $p = 0.041$), and waist-hip-ratio (−3.5 vs. +0.2%, $p > 0.001$). Maximum isometric strength significantly ($p < 0.001$) increased in the EG, while strength parameters decreased in the CG (−0.5 to −6.4%). Thus, the study demonstrated that multipurpose high-intensity exercise programs significantly affect relevant menopausal risk factors and, therefore, may be individually considered as an alternative to hormone replacement therapy.

KEY WORDS. early-menopausal women, exercise, BMD, CHD, body composition, osteoporosis

INTRODUCTION

The early menopause is associated with negative effects on most tissues with estrogen receptors including muscle, bone, fat, brain, and the central nervous system (9, 34). For many years hormone replacement therapy (HRT) has been the most important therapeutic agent to offset estrogen depletion and to manage menopause. However, since the results of the Women's Health Initiative study showed that HRT increased cardiovascular risk (53), alternative options are now required.

One alternative may be exercise that has demonstrated favorable effects on coronary heart disease (CHD) risk factors (2, 21), early postmenopausal muscle/bone loss (2, 26), and menopausal symptoms (33, 42). However, it is important to state that there are numerous variations of exercise regimen that may emphasize speed, strength, power, endurance, or coordination. As specific stimuli cause specific adaptations, exercise protocols that focus on CHD risk factors generally differ from those that target muscle or bone strength. For example, endurance type exercises are primarily used to reduce CHD risk factors (21), whereas resistance-type exercises such as strength or power training are favored to improve muscle and bone strength (26).

Thus, for prevention of CHD and osteoporosis, this would mean that women should perform both endurance- as well as resistance-type exercise classes. Obviously, due to time constraints, it is unlikely that early postmenopausal women are willing to participate in several different exercise programs simultaneously (35). Therefore, it was the aim of this study to develop a multi-purpose exercise program and to show its effectiveness in reducing the impact of the most important early postmenopausal risk factors. In this article we focus on risk factors for CHD and osteoporosis.

METHODS

Experimental Approach to the Problem

The Erlangen Fitness Osteoporosis Prevention Study (EFOPS) is a prospective controlled exercise study in early postmenopausal women with osteopenia; the study was initially designed for a 3-year period and then extended for another 2 years using a slightly modified training regimen. The study was approved by the ethics committee of the University of Erlangen (Ethik Antrag 905) and the Office of Radiation Safety (S9108-202/97/1, S21-22112-81-00, Z2.1.2-22462/2-2002-016). All study participants gave written informed consent. Study design, recruitment strategies, measurements, and 1–3 year results of bone densitometry and various exercise-related variables such as muscle strength have been reported in detail earlier (27–29). Here we report the 4 year results taken 50 months after the start of the study.

Subjects

One hundred thirty-seven early-postmenopausal women (1–8 years postmenopausal) with osteopenia (determined by dual energy x-ray absorptiometry [DXA]; $-1\ SD >$ DXA-T-Score $> -2.5\ SD$) at the lumbar spine (LS) or hip were included in EFOPS. Exclusion criteria were known

TABLE 1. Timing of the Erlangen Fitness Osteoporosis Prevention Study (EFOPS) measurements.*

	Baseline	Follow-up 1	Follow-up 2	Follow-up 3	Follow-up 4
Time to study start	−2 months	14 months	26 months	38 months	50 months
Anthropometric data	x	x	x	x	x
DXA: L1–L3 and total hip	x	x	x	x	x
DXA: distal forearm	x	—	x	x	x
QUS calcaneus	x	x	x	x	x
Blood samples	x	—	x	—	x
Sport-specific tests	x	x	x	x	x
Questionnaire	x	x	x	x	x
Nutritional analysis	x	x	—	x	—

* DXA = dual energy x-ray absorptiometry; QUS = quantitative ultrasound.

osteoporotic fractures, secondary osteoporosis, medication and diseases affecting bone metabolism during the last 2 years before study start (including HRT), inflammatory diseases, cardiovascular diseases, low physical capacity (<75 W at cycle ergometry), and a history of athletic activity during the last 20 years.

Eighty-six subjects were enrolled in the exercise group (EG); 51 subjects joined the control group (CG). Participants of the exercise group underwent the training below; controls were asked to maintain their present lifestyle. The members of both groups were individually supplemented with cholecalciferol and calcium according to their nutritional intake.

Study Intervention

The exercise program consisted of 2 supervised group sessions (60–65 minutes) and 2 home training sessions (20–25 minutes). All participants filled out individual training logs for group- and home-training sessions that were analyzed every 8–12 weeks.

The initial 7 months of the EFOPS study were used as an adaptation and conditioning period in order to prevent injuries and to prepare subjects for higher exercise intensities. For example, the jumping sequence was not carried out during this early phase and the intensity of the strength training was very slowly increased (to 70% 1 repetition maximum [1RM]). However, for a more extensive description of the first 7 months of exercise training the reader is kindly referred to an earlier publication (27). Thus, in the following we describe the training program that was used after this phase in period.

The group sessions were divided into 3 sequences: warm up/endurance (20 minutes), jumping (3–5 minutes), and resistance training (35–40 minutes). The warm up/endurance part began with 5 minutes of running, followed by 5 minutes of games to promote unusual strain distribution (43) under weight-bearing conditions. Then 10 minutes of low- and high-impact aerobic exercises with a progressively increasing amount of high impact concluded this sequence. Heart rates (HR) averaged 70–85% HRmax during this phase. Peak ground reaction forces as measured by force plates (mtd-Systems, Neuburg v. Wald, Germany) were 1,224 ± 150 N during the running sequence and 1,445 ± 232 N during the (high-impact) aerobic sequence.

The jumping sequence consisted of 4 different multilateral jumping exercises (closed leg jumps, jumping jack, diagonal jumps, and lateral jumps with 1 leg landing), and 15 repetitions each were performed. Landing was performed with flexed ankles and knees and without heel strikes. Depending on exercise the jumping rate varied from 0.5 to 2 Hz. For the most intense jumping type, average peak ground reaction forces were 2,363 ± 462 N.

The strength training consisted of 2 different types of resistance training: 1 of 2 group sessions was carried out on machines (Technogym, Gambettola, Italy); the other used isometric exercises, elastic bands, and free weights. The following dynamic exercises were performed in the session using resistance machines: horizontal leg press, leg curls, bench press, rowing, leg adduction and abduction, abdominal flexion, back extension, lat pulley, hyperextension, leg extension, shoulder raises, and hip flexion. A concentric 2 second, eccentric 2 second protocol was used. Twelve weeks of periodized high-intensity resistance training (9–10 exercises with 1–4 sets 70–90% 1RM) were interleaved with 4–6 week transitional periods of lower intensity (50–55% 1RM) but higher volume (13 exercises with 2–3 sets). Participants trained according to individual training plans based on the 1RM tests (32) performed during the first and last week of the transition period. However, the numbers of repetitions did not focus on complete exhaustion of the subject.

During the second resistance training session, isometric (12–15 exercises, 2–4 sets, 6–10 seconds) and elastic band exercises (3 exercises with 2–4 sets and 15–20 repetitions) were carried out. In addition, 3 resistance exercises using free weights (squat/deadlift, 1-handed dumbbell rowing, and dumbbell chest press) were performed according to the periodized protocol described above.

The home training consisted of rope skipping (3 different sets with 20 repetitions), isometric exercises, belt training, and stretching exercises. Every 12 weeks, a new home training routine with more intense exercises replaced the existing protocol. All exercises carried out at home were intensively discussed and trained in the earlier group sessions.

In study year 4 we introduced the aspect of movement velocity (51) and the following changes were made: (a) The exercise group was split into 2 subgroups: a strength training group (SG) performed a concentric 4 second, eccentric 4 second protocol. A power training group (PG) performed a concentric fast/explosive, eccentric 4 second protocol. Before and during the rest periods of the strength training, a standardized stretching program (8–10 exercises with 1–2 sets and 30 seconds of passive stretching) was performed. (b) One of the two home sessions was converted into a group session. Two of the 3 group sessions were carried out on resistance machines, the third was a group gymnastics session. Thus, in study year 4, the training consisted of 2 weightlifting sessions (60 minutes each), 1 gymnastics session (60 minutes), and 1 home training session (25 minutes).

Measurements

Table 1 shows the timing of the measurements presented and discussed in this article. Protocols as well as the reliability of the tests have been described in detail in other publications (27, 28).

Anthropometry

Height was determined with a stadiometer and weight was measured with minimal clothing on digital scales. Body mass index was calculated as weight divided by height^2 (kg·m^{-2}). Circumferences were determined at several locations including the waist and the hip. Body composition was assessed with the bioimpedance technique (Tanita BF-305, Tokyo, Japan).

Bone Densitometry

Bone mineral density (BMD) was determined by DXA (QDR 4500; Hologic Inc., Bedford, MA) at the LS, proximal femur, and the forearm using standard protocols specified by the manufacturer. Quantitative ultrasound was performed at the calcaneus (Sahara, Hologic Inc.), also using standard protocols of the manufacturer. Two parameters, speed of sound (SOS) and broad band ultrasound attenuation (BUA) were measured.

Blood Lipids

After an overnight fast, blood was sampled in the morning. Blood samples were centrifuged with 3,000 rpm for 20 minutes, serum samples were frozen at −70° C. Levels of total cholesterol (TC), HDL-cholesterol (HDL-C), LDL-cholesterol (LDL-C), and triglycerides (all Olympus Diagnostica GmbH, Hamburg, Germany) were determined at baseline, and after 2 and 4 years.

Strength Parameters

Maximum isometric strength of various muscle groups (trunk flexors, extensors, hip flexors, leg adductors, abductors and arm flexors, extensors) was measured with a Schnell M3 isometric tester and a Schnell trainer dynamometer (Schnell, Peutenhausen, Germany) using the test protocol suggested by Tusker (49). All tests were supervised. A more detailed description of the test protocol including positioning was presented earlier (27).

Questionnaires

A detailed questionnaire was used to assess well-being, pain frequency and intensity at different skeletal sites, prestudy exercise levels, normal daily activity levels, and risk factors for osteoporosis. The follow-up questionnaires additionally contained sections to monitor disease incidence, changes in disease severity and intake of medication, lifestyle changes, or sport activities outside the EFOPS training program. For a more extensive description of the questionnaire, the reader is kindly referred to recent communications (25, 27).

Nutritional Analysis

Five-day dietary records were analyzed using Prodi-4.5/03 expert (Wissenschaftlicher Verlag, Freiburg, Germany). To increase accuracy, each participant was provided with digital scales. According to the calcium and vitamin D analysis results, study participants were supplemented with calcium and cholecalciferol to ensure a total daily intake of 1,500 mg of calcium and 500 IU of cholecalciferol.

Statistical Analyses

Data were analyzed using SPSS, (version 12.0; SPSS, Inc., Chicago IL). The t-tests were used to detect within-group changes (e.g., 14, 16, 38, 50 months to baseline) for normally distributed variables; otherwise the Wilcoxon test was used. Differences between exercise and control group relative to baseline (% changes after 14, 26, 38, 50 months) were analyzed with unpaired *t*- or Mann-Whitney *U*-tests. Additionally, between-group differences were analyzed using an analysis of variance with repeated measurement design. Within-group factor was the date of the measurement (baseline and 14 or 26 or 38 or 50 months), between-group factor was exercise vs. control. Both statistical methods demonstrated comparable results. All tests were 2-tailed, a 5% probability level was considered significant.

RESULTS

Sixty-one of the 86 women who had started in the exercise group completed the 50-month follow-up visit (drop-out rate: 29%). In the control group 34 of 51 women completed the 50-month follow-up (drop-out rate: 33%). Reasons for drop-out were (a) relocations/occupational changes (EG: $n = 10$; CG: $n = 6$), (b) deaths/diseases not related to training (i.e., asthma, tumor; EG: $n = 6$; CG: $n = 4$), (c) study-related reasons (EG: $n = 5$; CG: $n = 3$), and (d) loss of interest ($n = 4$ in each group). Another 26 subjects had to be excluded from the analysis according to the study protocol for the following reasons: (a) occurrence of diseases and medications affecting bone and cardiovascular system (EG: $n = 6$; CG: $n = 5$), (b) significant change of physical activity (CG: $n = 1$), (c) insufficient training frequency (<2 sessions per week averaged over 50 months [30]: $n = 14$). Thus, 41 subjects of the EG and 28 subjects of the CG were included in the analysis. The average ($n = 61$) weekly attendance rate in the EG was 2.42 ± 0.53 over 50 months.

Table 2 compares the most relevant baseline data between EG and CG. There were no significant differences in baseline data between the subjects included in the 4-year analysis and the initial cohort ($n = 137$). The differential effect of strength and power training has already been reported in a recent publication (51). Significant differences were observed for BMD of the lumbar spine and total hip but for none of the other variables discussed in the current investigation. Therefore, with the exception of densitometric parameters at the end of year 4, we pooled the results for the 2 exercise subgroups for the year 4 results.

Anthropometry

After 50 months of intervention, body weight decreased slightly ($p = 0.189$) in the EG by 0.6 kg vs. 0.1 kg in the CG ($p = 0.87$). Since we observed no changes of body height, a comparable development was determined for the BMI. No between-group changes were demonstrated for both parameters. Body fat (%) as measured by bioelectrical impedance analysis (BIA) significantly decreased in the EG (−3.3%, $p = 0.014$), while a slight increase (+1.3%, $p = 0.40$) was observed in the CG (Figure 1). Between-group differences were significant after 50 months (Figure 1).

For lean body mass, again changes were not significant (EG: +0.3%, $p = 0.30$ vs. CG: −1.0%, $p = 0.25$). Waist to hip ratio (WHR: −3.5%, $p < 0.001$) and waist circumference (−1.5%, $p = 0.019$) significantly decreased in the EG (Figure 1) but did not change significantly in the control group (WHR: +0.2%, $p = 0.79$; waist: +1.2%, $p = 0.057$). Between-group differences were significant for the waist to hip ratio only ($p = 0.002$).

TABLE 2. Baseline data of exercise and control groups for anthropometric variables and risk factors for coronary heart disease and osteoporosis.*

Variable	EG (n = 41)	CG (n = 28)
Age (y)	55.3 ± 3.4	55.5 ± 3.0
Height (cm)	164.2 ± 6.6	162.2 ± 7.1
Weight (kg)	66.6 ± 8.7	64.5 ± 10.2
Body fat (%)	35.7 ± 4.9	33.7 ± 6.0
Waist/hip-ratio	0.82 ± 0.05	0.81 ± 0.05
Age at menopause (y)	50.4 ± 3.3	50.6 ± 3.3
Energy intake ($kJ \cdot d^{-1}$)	8.223 ± 1497	8.180 ± 1090
Fat intake/energy rate (%)	36.4 ± 4.9	36.5 ± 5.5
Calcium intake ($mg \cdot d^{-1}$)	1.130 ± 284	1.007 ± 190
Phosphorus intake ($mg \cdot d^{-1}$)	1.344 ± 295	1.297 ± 200
Vitamin D intake ($\mu g \cdot d^{-1}$)	5.3 ± 4.8	4.4 ± 4.4
Osteoporosis of parents or siblings (% per group)	15%	21%
Corticosteroids (>5 $mg \cdot d^{-1}$) for more than 6 mo. during lifetime (% per group)	10%	11%
Coffee intake ($ml \cdot d^{-1}$)	771 ± 307	757 ± 331
Smokers (% per group)	12%	14%
Relative $\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	26.8 ± 5.2	26.8 ± 6.0
DXA PA L1-L4 ($g \cdot cm^{-2}$)	0.868 ± 0.074	0.878 ± 0.102
DXA total hip ($g \cdot cm^{-2}$)	0.850 ± 0.071	0.858 ± 0.075
DXA ultradistal radius ($g \cdot cm^{-2}$)	0.413 ± 0.049	0.403 ± 0.047
Total cholesterol ($mg \cdot dl^{-1}$)	239 ± 36	243 ± 31
HDL-cholesterol ($mg \cdot dl^{-1}$)	59.7 ± 11.3	66.1 ± 14.0
Triglycerides ($mg \cdot dl^{-1}$)	92.3 ± 33	87.7 ± 32

* EG = exercise group; CG = control group; DXA = dual energy x-ray absorptiometry; PA = posterior anterior. p value not significant.

Bone Densitometry

Changes of bone density are presented in Figure 2. In the exercise group BMD at the lumbar spine (+1.0%, p = 0.037) and femoral neck (−0.3%, p = 0.194) was maintained over 50 months but significantly ($p < 0.001$) decreased in the control group resulting in significant ($p < 0.001$) between-group differences. At the ultradistal radius in both groups, we observed a significant decrease of 4% ($p < 0.001$) after 2 years (BMD at the radius was not measured at year 1). Between years 2 and 4 BMD of the ultradistal radius did not change significantly in either group. Further, changes for years 3 and 4 did not significantly differ between both groups. Speed of sound and broadband ultrasound attenuation (not shown in Figure 2) showed results similar to the central DXA measurements. In the exercise group no changes were observed (SOS: 0.3%, p = 0.92; BUA: −1.0%, p = 0.43) while in the control group SOS and BUA significantly decreased (SOS: −1.0%, $p < 0.001$; BUA: −5.5%, p = 0.005).

Power training (PT) was more effective than strength training (ST) in the spine and the hip. Relative to year 3, the year 4 results showed significant differences between the power and the strength training group for lumbar spine (PT: +0.6 ± 2.1% vs. ST: −0.9 ± 1.7%, p = 0.023) and total hip BMD (PT: +0.1 ± 1.7% vs. ST: −1.1 ± 1.5%, p = 0.015).

Blood Lipids

As seen in Figure 3 after 50 months blood lipids showed favorable changes in the exercise group (TC: −6.1%, p = 0.011; HDL-C: +14.1%, $p < 0.001$; LDL-C: −2.2%, p = 0.52; triglycerides: −10.2%, p = 0.032). Changes in the CG were unfavorable (TC: +3.5%, p = 0.180; HDL-C: −7.1%, p = 0.047; LDL-C: +5.6%, p = 0.110; triglycerides: +27.5%, p = 0.024). After 4 years between-group differences were significant (p = 0.002 to 0.011) with the exception of LDL-C (p = 0.211).

Strength Parameters

After 50 months of exercise maximum isometric strength significantly (all $p < 0.001$) increased in the EG (trunk flexors: 29%; extensors: 37%; hip flexors: 38%; leg adductors: 26%; abductors: 15%; arm flexors: 35%; arm extensors: 26%), while isometric strength decreased in the CG (−0.5%, p = 0.711 [trunk extensors] to −6.4%, p = 0.027 [trunk flexors]). All between-group differences were significant ($p < 0.001$).

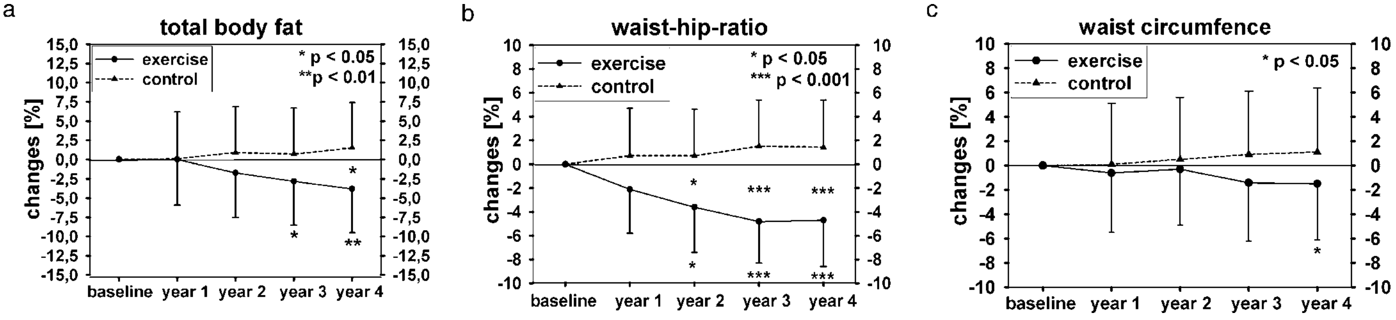

FIGURE 1. (a) Changes of total body fat, (b) waist to hip ratio, and (c) waist circumference in early postmenopausal women after 50 months of exercise.

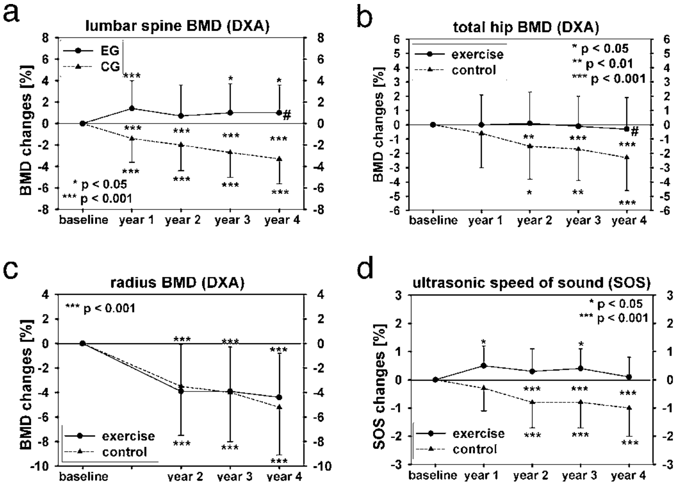

FIGURE 2. (a) Changes of lumbar spine bone mineral density (BMD), (b) total hip BMD, (c) ultradistal radius BMD as measured by dual energy x-ray absorptiometry (DXA), (d) speed of sound (SOS) as measured by quantitative ultrasound in early postmenopausal women after 50 months of exercise. EG = exercise group; CG = control group. # Significant differences between power and strength training groups after year 4 (see text).

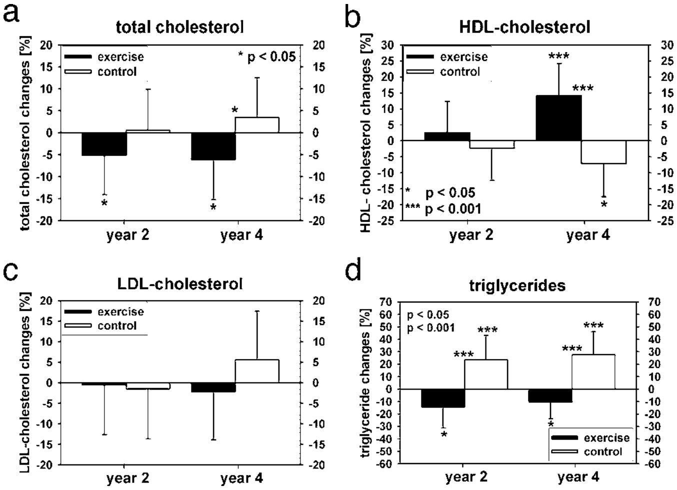

FIGURE 3. (a) Changes of total cholesterol, (b) HDL-cholesterol, (c) LDL-cholesterol, and (d) triglycerides in early postmenopausal women after 50 months of intervention.

Nutritional Intake

No significant changes of nutritional intake parameters affecting bone metabolism or CHD-risk factors (energy, fat, carbohydrates, proteins, calcium, phosphorus, magnesium, vitamin D, cholesterol, etc.) were found during the study.

DISCUSSION

In this communication we clearly demonstrated the benefit of a long-term multi-purpose exercise program for early-postmenopausal women. This result is not trivial since strategies to affect the most important (early-) menopausal risk factors, CHD and osteoporosis, differ widely. So far common exercise regimens to improve CHD risk factors largely focus on endurance (19, 21) with low intensity and moderate- to high-training volume. However, such protocols are suboptimal for bone (31); here high-intensity resistance programs dominate. Still it is questioned whether an exercise program with low-training volume (≤3 hours/week) can simultaneously benefit bone mineral density, body fat, blood lipids, and the brain or the central nervous system.

The EFOPS protocol is composed of a mix of endurance, jumping, and resistance exercises with high-exercise intensity and low-training volume. Our strategy was rather pragmatic: since most people are unwilling to spend a lot of time for prevention activities, the available time should be used most effectively. In order to optimize training effects under the constraints of a limited training volume, we applied modern training strategies (1) developed for athletic performance (4, 8). One central feature of our exercise protocol was regular change and adaptation of the training regimen which required a periodization to structure the macro- as well as the mesocycles (1). With respect to macrocycles, 12 weeks of high-intensity training were interleaved with 4–6 weeks of more regeneration exercises. During the mesocycles we used step loading periodization with 2–3 weeks of increasing intensity and 1 regenerational week afterwards.

Although this strategy was specifically applied during the resistance sequence, we also periodized the other training sequences using the length of the high impact sequences or the number of jumps per session. However, it should be emphasized, that despite high-exercise intensity, subjects did not exercise until complete exhaustion. Also, during the resistance sequence individual training plans did not call for the maximum possible repetitions for a given workload. We attribute the low injury rate of our study (1 hairline fracture, 1 periostitis, and 2 pulled muscles) to this nonexhaustive strategy as well as to the 7 months phasing-in period at the start of the study and to the intermediate regeneration phases.

Body weight, body fat, and fat distribution are regarded as independent predictors of CHD (54). Many studies (15, 17, 37) associate the menopausal transition with severe changes of these anthropometric parameters. However, in our control group we found only minor and statistically nonsignificant changes for body weight, BMI, body fat, waist circumference, and WHR, whereas for total body fat, waist circumference, and WHR, significant improvements (Figure 1) were observed in the EG. This is in contrast to the literature. The majority of longitudinal exercise studies in early (up to 10 years) postmenopausal women failed to demonstrate significant reductions of body fat in their exercise groups. Also, we did not find a study that reported significant effects on fat distribution in early postmenopausal exercise groups. However, the use of waist to hip ratio as a parameter to measure fat distribution is a limitation and inferior to regional body composition measurements by quantitative computer tomography (QCT) or MRI.

The EFOPS training program favorably affected blood lipids. As seen in Figure 3 the positive trend after year 2 was more obvious after year 4. With the exception of LDL-cholesterol all between-group differences were significant. In order to value this result it is important to note that relevant nutritional intake parameters did not change. In a recent literature review Asikainen et al. (2) identified 5 of 10 randomized trials that favorably affected blood lipids in early postmenopausal women. However, a comparison with our results is difficult because the survey covered the age range of 50 to 65 and, therefore, included studies with older postmenopausal women. Also 2 studies that showed positive effects (20, 47) combined diet or HRT with exercise without reporting data of a pure exercise group.

Moreover, pooling exercise studies may not be adequate if the training is different. For example, Asikainen et al. (3) who performed a walking training with women (1–10 years postmenopausal) either once (48 minutes) or twice (25 minutes) a day (5 days per week), failed to demonstrate significant effects on blood lipids, but their study was fundamentally different from our design. While Asikainen et al. (3) focused on continuous walking training with low-moderate intensity (65% $\dot{V}O_2$max) and higher volume (≈250 minutes per week), we performed blocks of periodized training with moderate- to high-intensity endurance/jumping and high-intensity resistance exercises on machines, interleaved by regenerational phases with lower intensity as described above. The results of these 2 studies indicate that short intense bouts of exercise seem to more adequate to favorably affect blood lipids.

Accelerated bone loss is the second major problem of early postmenopause (38). For our study we choose an interval of 1–8 years after menopause that includes the phase of rapid bone loss immediately after menopause and the transition to the subsequent period of lower bone loss rates (5, 12). It is highly important that during early menopause BMD can be stabilized. We showed that in the central skeleton, but not in the forearm, this can be achieved with adequate exercise over 4 years. Despite individually tailored calcium and vitamin D supplementation, BMD at the spine and hip decreased constantly in the control group. In the forearm in the first 2 years we observed a similar BMD decrease in both the exercise and the control group by 4% and a stabilization in both groups afterwards (Figure 2).

We recently reviewed exercise effects in early postmenopausal women (26). Eleven studies (7, 10, 11, 18, 20, 24, 36, 40, 41, 46, 50) reported exercise effects on bone mineral density and content. In the lumbar spine 4 (18, 30, 36, 41) of 8 studies observed significant differences between exercise and control groups. At the proximal femur 2 (20, 24) of 8 and at the distal forearm site 1 (10) of 3 studies (10, 36, 40) reported significant between-group differences with more favorable effects in the EG. The review showed that independent of exercise type, high-intensity exercises were a common element of those studies that showed positive effects on bone. Interestingly with 1 exception (18), jumping exercises, which were effective in premenopausal woman (6, 46) failed to increase BMD at the LS and proximal femur in postmenopausal women. Indeed, according to the set point theory proposed by Turner (48), hormonal depletion may increase the bone threshold for mechanical loading. However, strain variables (i.e., strain magnitude and rate) of jumping exercises or movements performed with high velocity in general (51) should exceed this mechanical threshold by far.

Besides the specific menopausal risk factors discussed above, strength is an important variable influencing general health, falls, independence, and quality of life. In the EG, isometric strength changes were in the range of our expectation. However, the strength decrease in the control group during 4 years is relatively small (−0.5 to 6.4%) and does not confirm the suggestion of some authors (14, 44, 45) that the accelerated loss (13, 16, 22, 39) of muscle mass and strength during the (early-) menopause is a main reason for the accelerated bone loss during this period.

Our study possesses several strengths but also some limitations. (a) We specifically focused on early postmenopausal women, a population at increased risk for CHD and osteoporosis. According to the recommendations of other researchers (5, 12), we selected a narrow interval of 1–8 years for the definition of early postmenopause. (b) We simultaneously targeted risk factors for CHD and osteoporosis. (c) As shown in Table 2 at baseline there were no differences between the exercise and control group in a large variety of relevant parameters. Further potential covariates were strictly controlled throughout the study. (d) Calcium and vitamin D supplements were adjusted according to the individual nutritional intake analysis. (e) Subjects with low training attendance were excluded from the data analysis. (f) The study was longer, testing intervals were shorter, and the number of subjects included was higher than in all other prospective exercise studies that focus on exercise/bone interaction published so far (55). (g) The exercise protocol regularly changed to provide new stimuli for muscle, bone, and the cardiovascular and central nervous systems. (h) Drop-out and injury rates were relatively low (drop-out after 50 months: EG 29 vs. CG 33%) (52); thus, our training was attractive and safe.

On the other hand: (a) We used a nonrandomized study design. However, contrary to placebo-controlled pharmaceutical studies, exercise studies with nontraining control groups cannot be blinded. Therefore, participants of randomized exercise studies often refuse to join the study arm they do not prefer. Thus, they drop out, may not fully comply (EG), or exercise without reporting (CG), causing a severe bias. There are conflicting data concerning the results of randomized vs. nonrandomized study designs. With respect to bone, Wolff et al. (55) concluded in their meta-analysis that nonrandomized studies showed an exercise effect nearly twice as high as randomized studies, whereas the meta-analysis performed by Kelley at al. (23) demonstrated the opposite effect (effect size randomized studies: 1.08 vs. nonrandomized studies: 0.44). Thus, although we accept the argument that nonrandomization may lead to an increased motivation of the exercise group, we speculate that the bias induced by nonrandomization may largely be offset by the problems of randomized nonblinded protocols. (b) As described in the Method section, the resistance protocol changed after 3 years of exercise. The 2 protocols (strength or power training) did not significantly differ in their impact on anthropometric parameters or CHD risk, but power training was more effective to maintain bone at the spine and the hip (51). Thus, the pooling of the data for these 2 measurements may be problematic.

PRACTICAL APPLICATIONS

Hormonal depletion generally shows negative effects on tissues with estrogen receptors. However, although HRT favorably impacts some menopausal risk factors and complaints, overall health risks may exceed benefits (53).

Comparably to HRT, exercise affects a multitude of systems and, therefore, may be an alternative option for early menopausal women. Indeed, considering all results, it is possible to design multiple purpose exercise programs that simultaneously have a positive influence on several early menopausal risk factors and physical fitness with reasonable training volume. It is interesting that apparently noncompatible endpoints, for example fat loss and bone maintenance, can be positively affected at the same time. Thus, we conclude that depending on the individual risk factor profile, exercise may be considered as an alternative to HRT in early postmenopausal women.

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