Bone Vol. 30, No. 6
June 2002:836–841

Stronger Back Muscles Reduce the Incidence of Vertebral Fractures: A Prospective 10 Year Follow-up of Postmenopausal Women

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The long-term protective effect of stronger back muscles on the spine was determined in 50 healthy white postmenopausal women, aged 58–75 years, 8 years after they had completed a 2 year randomized, controlled trial. Twenty-seven subjects had performed progressive, resistive back-strengthening exercises for 2 years and 23 had served as controls. Bone mineral density, spine radiographs, back extensor strength, biochemical marker values, and level of physical activity were obtained for all subjects at baseline, 2 years, and 10 years. Mean back extensor strength (BES) in the back-exercise (BE) group was 39.4 kg at baseline, 66.8 kg at 2 years (after 2 years of prescribed exercises), and 32.9 kg at 10 years (8 years after cessation of the prescribed exercises). Mean BES in the control (C) group was 36.9 kg at baseline, 49.0 kg at 2 years, and 26.9 kg at 10 years. The difference between the two groups was still statistically significant at 10 year follow-up ($p = 0.001$). The difference in bone mineral density, which was not significant between the two groups at baseline and 2 year follow-up, was significant at 10 year follow-up ($p = 0.0004$). The incidence of vertebral compression fracture was 14 fractures in 322 vertebral bodies examined (4.3%) in the C group and 6 fractures in 378 vertebral bodies examined (1.6%) in the BE group (chi-square test, $p = 0.0290$). The relative risk for compression fracture was 2.7 times greater in the C group than in the BE group. To our knowledge, this is the first study reported in the literature demonstrating the long-term effect of strong back muscles on the reduction of vertebral fractures in estrogen-deficient women. (Bone 30:836–841; 2002)

Key Words: Compression fracture; Back strength; Aging; Bone mineral density (BMD).

Introduction

Reduction in the biomechanical competence of the axial skeleton can result from the parallel decline in bone and muscle mass with aging. Inactivity also may contribute to this decline.[18] Participation in a strength training program can decrease the risk of falls and fractures of the lower extremities.[21]

One study of the effect of strengthening exercises for back extensor muscles in healthy postmenopausal women demonstrated a significant increase in back extensor muscle strength and improvement of posture, but not bone mineral density (BMD).[10] However, results of previous studies have been inconsistent; some have demonstrated improvement in muscle strength with exercise but not in BMD,[3,8,13,15,23,28] whereas others depicted improvement in muscle strength and BMD of the lumbar spine in estrogen-deficient women.[14,22]

Subject compliance with prescribed exercise interventions presents a challenge. In one 3 year controlled, randomized study of healthy premenopausal women, the dropout rate was 34% in the exercise group and 22% in the control group.[27] Even in studies of shorter duration (i.e., 2 year trial of brisk walking in postmenopausal women), 41% attrition was noted in both areas of the study.[6] Subjects who are not self-motivated may not continue with prescribed exercise programs.[20] However, compliance with a short-term exercise program has been more satisfactory.[12]

We hypothesized that: (1) stronger back muscles could reduce the risk of vertebral compression fractures; and (2) some of the muscle strength achieved through strengthening exercises may persist even several years after cessation.

The objective of this prospective study was to determine the long-term protective effect of stronger back muscles on the spine. In this controlled trial, 8 years after cessation of a 2 year course of back-strengthening exercises, we investigated whether increased muscle strength had any effect on the development of age-related changes such as muscle strength, BMD, or development of vertebral compression fractures.

Materials and Methods

Study Population

Of 100 volunteers, 68 met the inclusion criteria.[28] Later in the process of evaluation and enrollment, one subject withdrew because she was moving from the area, one withdrew for lack of interest, and one was hospitalized for hemorrhagic duodenal ulcer. Thus, 65 healthy white, postmenopausal, nonsmoking

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8756-3282/02/$22.00
PII S8756-3282(02)00739-1

Figure 1. Model demonstrating back-strengthening exercise with a backpack containing sandbag weights. (From Sinaki et al.[28] By permission of Mayo Foundation for Medical Education and Research.)

women were randomized and enrolled into a 2 year controlled, intensive, progressive back-exercise study (approved by our institutional review board). The average age of the subjects at the time of entry was 55.6 years (range 48–65 years). All had normal results on the following studies or determinations: electrocardiography, complete blood count, urinalysis, blood chemistry group, total thyroxine, parathyroid hormone, and 24 h urinary calcium. None of the subjects, by their own choice, were receiving calcium, vitamin D, or estrogen supplementation. Biochemical markers were normal in all subjects. They had not been consuming special diets that affect bone metabolism or muscle mass. None of the subjects had a recent history of back pain or back injury. Subjects were excluded if they had radiographic evidence of vertebral wedging or compression.

At baseline, subjects were randomly assigned to either a back-exercise (BE) or a control (C) group. Thirty-four women (average age 55.3 years) had been instructed to perform a progressive, resistive weight-lifting exercise program for the back extensor muscles. Using a backpack that contained weights equivalent to 30% of the maximal isometric back extensor strength (BES), each subject had been instructed to lift the backpack ten times in the prone position (**Figure 1**). As their back strength increased, the amount of weight lifted was increased. However, the maximal weight of the backpack was limited to 22.7 kg (50 lbs.). The exercises were performed at home once a day, 5 days a week. Thirty-one women served as controls (average age 55.9 years). Subjects in both groups were evaluated every 4 weeks for the duration of 2 years, and proper lifting principles and good posture were reviewed. Muscle strength and physical activity level were recorded at each 4 week visit for both groups.

After completion of the 2 year controlled back-exercise trial, the BE subjects discontinued the prescribed exercises. All subjects were informed about their calcium intake, BMD, and muscle strength, and each was advised to see her personal physician for ongoing medical care and pharmacotherapy to reduce bone loss. They were free to be involved in any self-selected physical activities and were not monitored. The subjects were informed at that time that we would be contacting them in the distant future for follow-up of their musculoskeletal health. Eight years later (10 years from baseline), the same subjects were asked to return for follow-up evaluation. Fifty of the 65 women, now aged 58–75 years, returned for 10 year follow-up: 27 from the BE group and 23 from the C group. Three subjects were unable to return because of a new geographic location, three had physical impairments (stroke, cancer, total knee arthroplasty), eight were unable to return for personal reasons, and one had died. All subjects were required to sign institutionally approved informed consent before initiation of their follow-up evaluations. The average age was 65.3 years (range 58–72 years) for the women in the BE group and 66.8 years (range 59–75 years) for the women in the C group.

The 50 subjects were reevaluated with procedures, questionnaires, and laboratory tests identical to those used at baseline and previous follow-up evaluations. Medical records and histories of all subjects were reviewed. A few subjects had received hormone replacement therapy during the 8 year period. However, none had had this therapy for longer than 4 months, citing several concerns for discontinuation, including breast cancer, headaches, and weight gain. Anthropometric measurements, including height in centimeters and weight in kilograms, also were obtained. Examiners, blinded to subject grouping and independent of each other with no knowledge of test results, evaluated muscle strength, physical activity, radiographs, and BMD.

Radiographs

Radiographs of the spine were obtained at a standard target-to-film distance. Radiographs from the previous and the current study were compared with a method previously described.[9] All radiographs (T-4 through L-5) were reviewed by two radiologists independently (D.A.C. and R.G.) for evidence of compression fractures in the spine. Each vertebra was assessed visually. Any reduction of anterior, middle, or posterior height of 20% or more was considered a compression fracture in the analysis.[30] Results of the two evaluations were reviewed by a clinician blinded to the subjects' original grouping.

Muscle Strength

Isometric strength of back extensors and grip were measured with strain-gauge isodynamometers.[16,27] Interexaminer variation was eliminated by having the same examiner obtain the measurements in all subjects. In our laboratory, the technique for measuring BES showed a coefficient of variation of 2.3%, and that of grip strength was 2%.

Bone Mineral Density

The BMD of the anteroposterior lumbar spine (L2–4) was measured with a QDR-2000 instrument (Hologic, Inc., Bedford, MA). Measurements from the baseline and 2 year evaluations that were performed with dual-photon absorptiometry were recalculated with a conversion formula designed to compare dual-photon absorptiometry values with dual energy X-ray absorptiometry values. Quality control procedures in the laboratory are established to permit longitudinal comparisons of measurements of $\geq$8 y apart.[31] The machine was standardized daily with an aluminum tube standard. Precision was 1% (coefficient of variation).

Physical Activity

Routine weekly physical activity was assessed through the use of a questionnaire based on a previously published standardized scale (Physical Activity Score) that reflects the total level of daily physical activities, including homemaking (0–6), job (0–6), and sports (0–6).[26] This questionnaire has been designed to assess the level of daily physical activity by converting the amount of weight-lifting and walking involved in housework,

Table 1. Follow-up data for 50 postmenopausal healthy women: control and back exercise (BE) groups

	Baseline		2 year follow-up		10 year follow-up		
Variable	Control[a] (n = 23)	BE[a] (n = 27)	Control[a] (n = 23)	BE[a] (n = 27)	Control[a] (n = 23)	BE[a] (n = 27)	P[b]
Age (yr)	56.8 ± 4.5	56.8 ± 4.5	—	—	66.8 ± 4.5	65.3 ± 4.3	n.s.
Height (cm)	161.3 ± 4.7	162.6 ± 4.9	161.0 ± 4.6	162.4 ± 4.8	159.6 ± 4.5	161.2 ± 4.9	n.s.
Weight (kg)	62.4 ± 7.4	66.3 ± 9.4	62.0 ± 8.5	66.7 ± 9.9	63.6 ± 10.1	67.8 ± 11.8	n.s.
BES (kg)	36.9 ± 10.3	39.4 ± 8.9	49.0 ± 12.6	66.8 ± 15.8	26.9 ± 7.4	32.9 ± 8.4	0.0357
Grip (D) (kg)	26.0 ± 4.4	27.4 ± 5.4	25.9 ± 3.9	29.2 ± 5.8	28.3 ± 5.0	29.4 ± 6.3	n.s.
PAS	7.4 ± 2.5	8.3 ± 2.3	11.7 ± 3.3	10.3 ± 3.4 (14.3 ± 3.1)[d]	6.3 ± 2.1	8.0 ± 2.5	0.0106[c]
LS BMD	1.00 ± 0.15	1.07 ± 0.16	0.98 ± 0.15	1.03 ± 0.16	0.82 ± 0.15	0.89 ± 0.14	0.0004
No. of vertebral compression fx	0	0	0	0	14 (322) (4.3%)	6 (378) (1.6%)	0.0290[e]

KEY: BES, back extensor strength; fx, fracture; grip (D), grip strength of dominant hand; LS BMD, bone mineral density of lumbar spine; n.s., not significant; PAS, physical activity score.
[a]Values expressed as mean ± standard deviation.
[b]Tested with paired t-test between 2 and 10 year follow-up.
[c]Tested with Wilcoxon rank sum test.
[d]PAS level with back-exercise program added.
[e]Chi-square test.

job, and sports into METs (1 MET is the metabolic oxygen requirement under basal conditions, which is equal to the basal metabolic rate).[1,2] The reproducibility of technique for the same examiner has demonstrated a coefficient of variation of 2.3%.[26] Compliance was assessed by regular interviews with subjects in both groups.

Statistical Analysis

With the follow-up period as a within-group factor, exercise-control grouping as a between-group factor, and the baseline variables such as age, body height, body weight, physical activity score, back extensor strength, grip strength, and BMD as covariates, a two-way repeated-measures analysis of covariance (ANCOVA) was performed to determine the effect of these factors on the radiographic and other variables. BES was analyzed with a one-way repeated measures analysis of variance because there was a significant interaction ($p < 0.0001$) between the two grouping factors. The physical activity score was analyzed by Kruskal–Wallis one-way analysis of variance. When a significant effect was observed, the Tukey test was used to further characterize the significance of the specific differences. Statistical significance was set at $p < 0.05$. With 23 subjects in one group and 27 in another, there was a 90% power to detect a difference in means between any two of the measurements that is equal to 1.0 standard deviation ($\alpha = 0.05$, $\beta = 0.1$). Regarding the chi-square test to analyze the fracture incidence, the statistical power of the test was calculated to be 85% ($\alpha = 0.05$, $\beta = 0.15$) to detect a 10% difference in fracture incidence using the number of vertebral bodies (n = 322, vs. 378), and 80% ($\alpha = 0.05$, $\beta = 0.2$) to detect a 30% difference in fracture incidence using the number of subjects (n = 23, vs. 27).

Results

Data for both study groups are summarized in **Table 1**. There were no dropouts from either group in the first 2 years of the study, and 77% of the subjects were available for follow-up at 10 years (27 of 34 BE subjects [79%] and 23 of 31 C subjects [74%]). On review of the subjects' medical records and histories, none had had a hip fracture. All were nonsmokers with minimal or no alcohol intake. Although some of the subjects had been prescribed estrogen during the 8 year poststudy period, none of the subjects had been receiving estrogen or other pharmacotherapy known to affect bone mass on a regular basis (>4 month duration). There was no significant difference between the subjects' dietary or calcium intake. Body height was not significantly different between the groups at baseline ($p = 0.29$). It decreased in both groups over the 10 year period from a mean of 162.6 to 161.2 cm in the BE group (0.86%) and from a mean of 161.3 to 159.6 cm in the C group (1.05%) (repeated measures ANCOVA, $p = 0.0001$) (**Figure 2**).

Radiographs

The incidence of vertebral compression fracture was 14 fractures in 322 vertebral bodies examined (4.3%) in the C group and 6 fractures in 378 vertebral bodies examined (1.6%) in the BE group (chi-square test, $p = 0.0290$). The relative risk for compression fracture was 2.7 times greater in the C group than in the BE group. We defined wedging as <20% loss in vertebral height.[30] The incidence of wedging deformity was 9 wedges in 322 vertebral bodies examined (2.8%) in the C group and 6 wedges in 378 vertebral bodies examined (1.6%) in the BE group (chi-square test, $p = 0.27$). The number of subjects with fractures

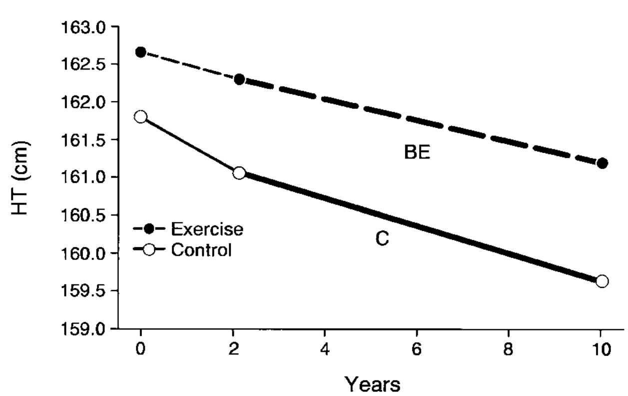

Figure 2. Body height (HT) in two study groups: back exercise (BE) and control (C). There was no significant difference between the groups, but in both groups body height decreased significantly during the 10 year period ($p < 0.0001$).

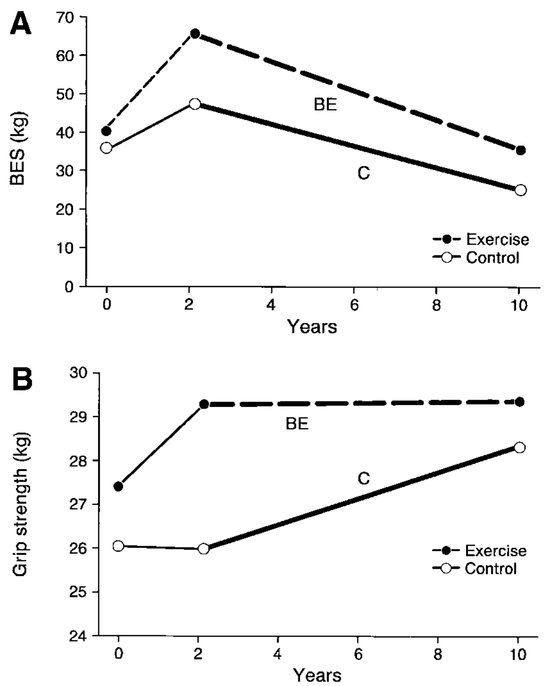

Figure 3. Muscle strength in two study groups: back exercise (BE) and control (C). Subjects participated in self-selected physical activities during years 3–10. (A) Back extensor strength (BES). In both groups, BES increased at 2 years ($p = 0.0001$) and decreased at 10 years ($p = 0.0001$). The BES of the BE group was significantly greater than that of the C group at both 2 years ($p = 0.0005$) and 10 years ($p = 0.0357$). The values are mean ± SD. (B) Grip strength increased significantly in both groups ($p \leq 0.0035$), but there was no significant difference between the groups at 10 year follow-up ($p = 0.61$).

was 7 of 23 (30.4%) in the C group and 3 of 27 (11.1%) in the BE group ($p = 0.0853$).

The degree of thoracic kyphosis increased significantly in both groups (repeated measures ANCOVA, $p = 0.0024$), as did the degree of lumbar lordosis (repeated-measures ANCOVA, $p = 0.0001$) and the degree of sacral inclination (repeated-measures ANCOVA, $p = 0.\ 0007$).

Muscle Strength

Initially, BES was not significantly different between the two groups (BE, 39.4 kg; C, 36.9 kg; $p = 0.36$). By the end of the 2 year exercise course, BES was significantly higher in the BE group (66.8 kg) than in the C group (49.0 kg) (repeated-measures ANCOVA, $p = 0.0005$) (**Figure 3**A). At 10 years, the BE group had lost 16.5% of their baseline back strength (39.4 to 32.9 kg), whereas the C group had lost 27.1% (36.9 to 26.9 kg) (Figure 3A). The difference between the two groups was statistically significant at 10 year follow-up ($p = 0.0357$). BE subjects had an average back muscle strength loss of 1.65% per year, whereas C subjects lost 2.7% per year.

Grip strength increased significantly in both groups ($p < 0.0035$), but there was no significant difference between the groups at 10 years ($p = 0.61$) (Figure 3B).

Bone Mineral Density

At 10 year follow-up, BMD of the lumbar spine decreased significantly in both groups ($p = 0.0001$). Assuming a linear loss in the 10 year period (estimated to be 0.02 g/cm^2 per year, and again comparable for both groups) (**Figure 4**), this finding is within the normal range of age-related bone loss for gender and age.[30] Although the difference in BMD between the groups was not statistically significant at baseline ($p = 0.13$) nor at 2 years ($p = 0.44$), at 10 year follow-up the difference in BMD between the groups was statistically significant ($p = 0.0004$).

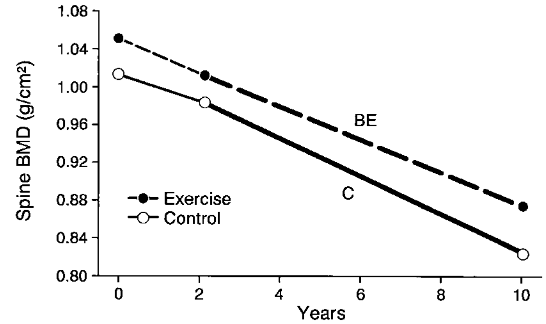

Figure 4. Bone mineral density (BMD) of lumbar spine in two study groups: back exercise (BE) and control (C). Subjects participated in self-selected physical activities during years 3–10. There was no significant difference in BMD between the groups at baseline ($p = 0.13$) or at 2 year follow-up ($p = 0.44$). BMD decreased significantly in both groups at 10 years ($p = 0.0001$). At 10 year follow-up, the difference in BMD between the groups had become significant ($p = 0.0004$).

We correlated body weight with BMD in the 50 women, regardless of group assignment. The correlations were as follows: baseline, $r = 0.334$, $p = 0.018$; 2 year follow-up, $r = 0.440$, $p = 0.001$; 10 year follow-up, $r = 0.340$, $p = 0.016$.

Physical Activity Scores

Initially, physical activity level was not significantly different in the two groups. During the 2 year course, physical activity level increased in both groups but was significantly higher in the exercise group ($p = 0.0092$) only when the obligatory back exercises were included in the physical activity scores (Table 1). At the 10 year follow-up, the scores were lower in both groups, but still higher in the BE group ($p = 0.0106$) (**Figure 5**). Analysis of the three components of the physical activity score showed that this was due to higher scores in all categories, especially for physical activities related to their job, in the BE group.

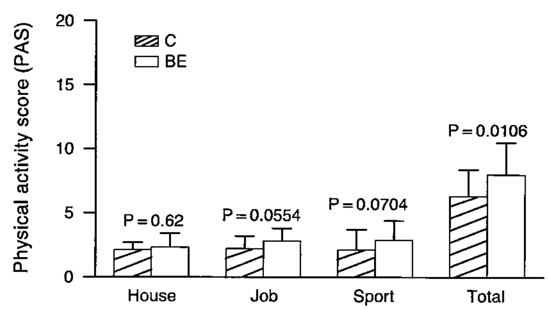

Figure 5. Physical activity score (PAS) at 10 year follow-up in two study groups: back exercise (BE) and control (C). PAS was significantly higher in the BE group than in the C group ($p = 0.0106$). Values are expressed as mean ± SD.

Discussion

In this study, we evaluated the long-term effect of stronger back muscles on the spine in estrogen-deficient women. The data showed that although vertebral bone loss was comparable in both groups, the BE group had fewer than half as many vertebral fractures as the control group, even 8 years after cessation of the back-strengthening exercises. The difference in BMD between the groups was not statistically significant at baseline nor at 2 year follow-up. However, at 10 year follow-up, even though BMD had decreased significantly in both groups, the difference between the groups had become statistically significant ($p = 0.0004$). Higher Physical Activity Scores and BES may not be the sole contributors to BMD, but they may be factors that affected the BMD in the BE group at 10 year follow-up. This may also have contributed to the fewer compression fractures in the BE group. No one in either group had sustained a hip fracture, even though the incidence of hip fracture in this geographic location for this age group has been reported to be 385/100,000 per year (95% confidence interval, 356–413), or 3.85/1000 per year between the years 1985 and 1992. This incidence is quite similar to that reported for whites in the USA for this age group from 1988 to 1989 (394/100,000 per year) when comparably adjusted to 1990 whites in the USA aged 50 years or older.[17] The data also demonstrated that the prescribed progressive, resistive back-strengthening exercise program was sufficient to significantly improve back muscle strength in the BE group. Coincidentally, the C subjects showed an improvement in their back strength (although much less than in the BE group) during the 2 year study. Perhaps this was a result of the periodic review of proper posture principles and the back strength measurements that were performed every 4 weeks for 2 years. However, 8 years after cessation of the 2 year exercise course, BES was still significantly greater in the BE group ($p = 0.0109$). Back muscle strength has been shown to decrease by about 50.4% in women between the ages of 50 and 80 years, which is about 2.5% per year.[25] Subjects in the current study, however, had an average loss in back muscle strength of about 1.65% per year in the BE group and 2.7% per year in the C group. Thus, the benefit of a 2 year course of progressive, resistive exercises was still apparent 8 years after cessation of the prescribed exercise course.

Detailed analysis of our physical activity data showed that subjects who had been involved in jogging or in the care of small children 8 years previously no longer participated in these activities. However, all of the subjects had continued with their daily routine physical activities and some had increased recreational physical activities such as crocheting, gardening, and knitting. These might explain the significant increase in grip strength.

In a recently published study, follow-up evaluation of decreased height was based on the patient's report of baseline height.[24] In this study, because we had recorded height measurements at baseline, we were able to document actual height changes. Although both groups showed significant decreases in body height, there was no statistically significant difference between the groups at 0, 2, or 10 years. Reduction of height with aging has been previously reported.[4]

That BMD is a consequence of good musculoskeletal health is a well-accepted fact. However, the role of muscle strength in the maintenance of musculoskeletal health has not received adequate attention or credit in the literature. Building muscle strength has been shown to be beneficial not only for slowing bone loss or even increasing bone mass but also for reducing falls and trauma as causes of bone fracture. If exercise is not sufficient to reduce bone loss or increase bone mass, a beneficial effect can be expected from increases in muscle strength alone. A previous study has shown that exercise-induced bone gain is only temporary, and pre-exercise levels are obtained when the activity is stopped.[11] Gained muscle strength and bone mass also decrease with inactivity.[5,11,19] However, in postmenopausal women, participation in long-term recreational gymnastics or folk dancing has been associated with improved muscle strength and body balance.[29]

Regular strength training has been demonstrated to slow the loss of muscle function.[7] Despite the benefits of exercise, however, poor compliance remains a problem and often interferes with regular participation in an exercise regimen. Realistically, people are not monitored on a monthly basis for compliance with their physical exercise.

In summary, benefits from participation in a 2 year back exercise course continued even 8 years after cessation. Even though there was no apparent bone gain in the exercise subjects initially, improvement of back strength could have reduced the risk of vertebral fractures later in life. Thus, the finding supports the fact that other extraskeletal benefits are derived from exercise. Because compliance is difficult to maintain,[20] perhaps consideration of periodic short-term courses of intensive exercise would be more beneficial than long-term programs, in terms of both compliance and maintenance of musculoskeletal health. These prospective data provide good evidence to warrant further investigation of this topic.

Acknowledgments: This study was supported in part by Grant RR 00585 from the National Institutes of Health, a grant from the Retirement Research Foundation, and a grant from Donaldson Charitable Trust. The authors thank Sandy Fitzgerald for her efforts in contacting and scheduling the subjects for follow-up and for secretarial support.

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Date Received: May 10, 2001
Date Revised: January 7, 2002
Date Accepted: February 7, 2002