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Exercise and Lumbar Spine Bone Mineral Density in Postmenopausal Women: A Meta-Analysis of Individual Patient Data

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Background. Low bone mineral density (BMD) at the lumbar spine is a major public health problem among postmenopausal women. We conducted a meta-analysis of individual patient data (IPD) to examine the effects of exercise on lumbar spine BMD in postmenopausal women.

Methods. IPD were requested from a previously developed database of summary means from randomized and nonrandomized trials dealing with the effects of exercise on BMD. Two-way analysis of variance tests with pairwise comparisons ($p \leq .05$) and 95% confidence intervals (CIs) were used to determine the statistical significance for changes in lumbar spine BMD.

Results. Across 13 trials that included 699 subjects (355 exercise, 344 control), a statistically significant interaction was found between test and group ($F = 15.232$, $p = .000$). Pairwise comparisons (Bonferroni t tests) revealed a statistically significant increase in final minus initial BMD for the exercise group ($\bar{X} \pm SD = 0.005 \pm 0.043$ g/cm^2, $t = 2.46$, $p = .014$, 95% CI = 0.001–0.009) and a statistically significant decrease in final minus initial BMD for the control group ($\bar{X} \pm SD = -0.007 \pm 0.045$ g/cm^2, $t = -3.051$, $p = .002$, 95% CI = −0.012–−0.002). Changes were equivalent to an approximate 2% benefit in lumbar spine BMD (exercise, +1%, control, −1%).

Conclusions. The results of this IPD meta-analysis suggest that exercise helps to improve and maintain lumbar spine BMD in postmenopausal women.

IT has been estimated that approximately 26.2 million postmenopausal women have either osteoporosis or osteopenia (1). As a result of having osteoporosis or osteopenia, a person is at an increased risk for fracture, particularly at the vertebrae, hip, and distal forearm (2). Of these three sites, fractures of the vertebrae, which represent approximately 56% of all fractures, are the most common, with an estimated 700,000 per year (2). The health-care costs associated with vertebral fractures were estimated to be approximately $746 million in 1995 and are expected to increase substantially in the future (3).

One of the potential interventions for increasing and/or maintaining vertebral bone mineral density (BMD) in postmenopausal women is exercise, a low-cost, nonpharmacologic intervention that is available to most individuals. We have recently conducted meta-analytic work in which we reported improvements in lumbar spine BMD because of exercise in postmenopausal women (4,5). This work was based on the most commonly used approach for conducting meta-analytic work, that is, the abstraction of summary means from studies meeting specified inclusion criteria. However, the use of individual patient data (IPD) versus summary means from eligible studies represents the most comprehensive approach for conducting meta-analytic work, including the potential for increased statistical power as well as a more thorough examination of potential covariates (6–8). Given the health-care consequences of low BMD at the lumbar spine, the possible benefit of exercise for improving and/or maintaining lumbar spine BMD, and the potential for a meta-analysis of IPD to provide more thorough information regarding the effect of exercise on lumbar spine BMD, we sought to examine the effects of exercise on lumbar spine BMD in postmenopausal women by conducting a meta-analysis using IPD.

METHODS

Data Sources

From a previously developed meta-analytic database that included the summary means from 76 studies dealing with the effects of exercise on BMD, we sought to obtain IPD. Briefly, IPD were requested by sending a cover letter and data request sheet to authors via postal mail. For those who did not respond to our initial request, a follow-up letter was sent via postal mail approximately 5 weeks later.

Study Selection

From the database of 76 studies, we included studies that met the following criteria: (i) randomized and nonrandomized trials that included a comparative control (nonexercise) group, (ii) exercise lasting at least 16 weeks, (iii) postmenopausal women only, (iv) journal articles, dissertations, and masters theses published in the English-language literature, (v) studies published between January 1966 and December

1998, (vi) BMD (relative value of bone mineral per measured bone area) assessed at the lumbar spine, and (vii) ability to obtain IPD from authors. Despite the fact that methods to assess BMD (dual-photon absorptiometry [DPA], dual-energy x-ray absorptiometry [DEXA]) have only been widely available since the 1980s, we searched back to 1966 to ensure that there was no comparative technology that we might have missed. We did not include studies from non-English-language journals because of the potential for error in the translation and interpretation of findings. If more than one study included the same subjects, for example, a dissertation and refereed journal article, we retrieved and referenced both studies to extract the maximum amount of information but only included this as one data set.

Data Abstraction

All data were abstracted on a coding sheet that could hold up to 91 pieces of information from each study. All data were coded and verified for accuracy and consistency by George A. Kelley. Blinding of the coder to the identity and institutional affiliation of the authors as well as study results was not performed because it has been shown that these procedures have neither a statistically significant nor a clinically important effect on the results (9). The major categories coded included study, subject, BMD assessment, and training program characteristics as well as primary and secondary outcomes.

Statistical Analysis

Initial subject characteristics.—Potential differences between initial subject characteristics for exercise and control groups were examined using independent *t* tests and 95% confidence intervals (CIs) for continuous variables and 2 × 2 chi-square tests for categorical variables.

Primary outcomes.—Initial and final values for lumbar spine BMD between exercise and control groups were examined by using a two-way analysis of variance (ANOVA) test with repeated measures on one factor (test). Because this was an unbalanced design, a General Linear Model was used. Pairwise comparison tests (Bonferroni *t* tests) were used to identify the specific location of the observed interaction between test (final vs initial) and group (exercise vs control). To examine for outliers, ANOVAs were performed with each study deleted from the model once. Because of missing data, we were unable to include potential covariates in the ANOVA model. Consequently, we used Pearson-Product moment correlations to examine for potential associations between changes in BMD and age, height, body weight, years postmenopausal, cigarette smoking, alcohol consumption, calcium and vitamin D intake, compliance (percentage of exercise sessions attended), length of training (weeks), type of BMD assessment (DEXA, DPA), and study design (randomized vs nonrandomized controlled trial). We were unable to partition the data according to the different types of exercise because of the various interventions employed.

Because of the inability to retrieve IPD from all eligible studies, we also examined whether our results differed between studies according to the availability of IPD. To include all eligible studies in the analysis, we used the standardized difference effect size (ES) calculated from the summary data reported in the studies and corrected for small sample bias (10). In general, an ES of 0.20 is considered a small effect, 0.50 a moderate effect, and 0.80 a large effect (11). An ES of 0.80, for example, means that the exercise group differed from the control group by eight-tenths of a standard deviation in favor of the exercise group. We then compared ES differences between those studies in which IPD were provided versus those in which they were not using an ANOVA-like random effects model developed for meta-analytic research (10). This was accomplished by examining the between (Q_b) and within (Q_w) group differences for the ESs and their variances from each group.

Secondary outcomes.—Secondary outcomes (body weight, calcium intake, and vitamin D intake) were analyzed using the same ANOVA procedures that were used to evaluate changes in lumbar spine BMD. We used independent *t* tests to analyze initial differences between exercise and control groups for these variables because more data were available for initial values versus final values and we wanted to capture as much data as possible in our analyses.

Descriptive Statistics and Alpha Level

Means and standard deviations ($\overline{X} \pm SD$) were used to describe continuous variables, whereas frequencies and percentages were used for categorical variables. The alpha level for statistical significance was set at $p \leq .05$. Ninety-five percent CIs that did not cross 0.00 were also considered statistically significant.

Results

Study Characteristics

Of the 32 studies that met our criteria for inclusion, we were able to retrieve IPD from 13 (41%) (12–26). Note that the number of references exceeds the number of studies because two were published in dissertation (17,24) and two in journal format (18,25). A description of the studies is shown in Table 1. The 13 studies represented a total of 30 groups (17 exercise, 13 control) and 699 subjects (355 exercise, 344 control). Seven of the trials were randomized controlled trials, and the remaining six were nonrandomized controlled trials. The length of the studies ranged from 24 to 104 weeks ($\overline{X} \pm SD = 56 \pm 8$ weeks). Thirteen of the exercise groups included some type of weight-bearing exercise, two appeared to perform nonweight-bearing exercise, and the remaining two participated in weight training. Compliance, defined as the percentage of exercise sessions attended, averaged 75 ± 17%. Seven of the studies assessed lumbar spine BMD using DEXA, whereas the remaining six used DPA.

Initial Subject Characteristics

Initial subject characteristics for continuous and categorical variables can be found in Tables 2 and 3, respectively. For continuous variables, the number of years that the subjects were postmenopausal was significantly greater in the control versus exercise groups, whereas calcium intake was

Table 1. Characteristics of Bone Mineral Density Studies (gm/cm^2) in Which IPD Were Provided for Postmenopausal Women at the Lumbar Spine

Study	Design/Subjects	Exercise Intervention(s)	BMD Assessment
Bloomfield and colleagues (12)	CT that included 18 postmenopausal women assigned to either an exercise (n = 7; age = 62.1 ± 2.1 years) or control (n = 11; age = 60.0 ± 9.4 years) group.	32 weeks of training performed 3× per week for 50 minutes per session (15-minute warm-up, 30 minutes of stationary cycling, 5-minute cool-down) at 60–80% of maximal heart rate.	DPA (Lunar DP3, Lunar Radiation, Madison, WI) at L1–L4.
Bravo and colleagues (13)	RCT that included 106 women assigned to either an exercise (n = 44; age = 59.8 ± 5.9 years) or control (n = 62; age = 60 ± 6.3 years) group.	52 weeks of training performed 3× per week for 60–65 minutes per session. Exercise sessions consisted of a 10-minute warm-up, 25 minutes of rapid walking replaced with aerobic dance 1× per week, and 15 minutes of bench stepping at 60–70% of MHRR. This was followed by 10–15 minutes of resistance exercise.	DEXA (Lunar DPX, Lunar Radiation) at L2–L4.
Brooke-Wavell and colleagues (14)	RCT of 76 postmenopausal women assigned to either an exercise (n = 37; age = 65.0 ± 2.8 years) or control (n = 39; age = 64.2 ± 3.1 years) group.	52 weeks of training that consisted of self-monitored walking 3.5 times per week for 14.8 minutes per day for the first 12 weeks, followed by 20.4 minutes per day of walking, 4.8 days per week, for the remainder of the study.	DEXA (Lunar DPX, Lunar Radiation) at L2–L4.
Caplan and colleagues (15)	CT of 30 postmenopausal women assigned to either an exercise (n = 19; age = 66.4 ± 5.0 years) or control (n = 11; age = 65.4 ± 4.9 years) group.	104 weeks of aerobic weight-bearing exercise performed 2× week for 60 minutes (warm-up, 20–25 minutes of low-impact aerobic exercise, 10 minutes of ball games for improved hand-eye coordination followed by work on floor mats for strength and flexibility, 10 minutes of relaxation). Subjects were also asked to exercise on their own 1× per week so that the pulse would be elevated for at least 20–30 minutes.	DPA (Lunar DPA, Lunar Radiation).
Ebrahim and colleagues (16)	RCT of 92 postmenopausal women assigned to either an exercise (n = 47; age = 66.4 ± 7.9 years) or control (n = 45; age = 68.1 ± 7.8 years) group.	104 weeks of walking 3× per week for 40 minutes per session.	DEXA (Lunar DPX, Lunar Radiation).
Grove (17), Grove and Londeree (18)	RCT that included 15 postmenopausal women assigned to either a low-impact exercise group (n = 5; age = 56.6 ± 43.3 years), high-impact exercise group (n = 5; age = 54.0 ± 1.9 years), or control group (n = 5; age = 56.0 ± 4.5 years).	52 weeks of training performed 3× week for approximately 60 minutes per session (15–20 minute warm-up, 20 minutes of either low- or high-impact exercise, 15-minute cool-down). Low-impact activities were considered those that produced forces less than 1.5× body weight, high impact ≥2.0× body weight.	DPA (Lunar DP3, Lunar Radiation) at L2–L4.
Iwamoto and colleagues (19)	CT that included 35 postmenopausal women assigned to either an exercise (n = 15; age = 64.8 ± 6.1 years) or control (n = 20; age = 64.8 ± 5.7 years) group.	52 weeks of outdoor walking (7 days per week) and gymnastic training (at least 5 days per week).	DEXA (Norland XR26, Norland Medical Systems, White Plains, NY) at L2–L4.
Little (20)	CT that included 21 postmenopausal women assigned to a resistance training (n = 6; age = 59.5 ± 2.3 years), walking (n = 6; age = 52.3 ± 4.5 years), swimming (n = 5; age = 51.8 ± 5.8 years), or control (n = 4; age = 60.8 ± 1.4 years) group.	Resistance exercise consisted of 32 weeks of training with 9 exercises performed 3 times per week for 1 set of 8–12 repetitions at 60%–80% of 1RM; Walking consisted of 32 weeks of training, 3× per week for 30–50 minutes per session (5–10-minute warm-up; walking for 20–30 minutes; 5–10-minute cool-down) at 70%–90% of maximal heart rate; Swimming consisted of 32 weeks of training, 3× per week for 30–50 minutes per session (5–10-minute warm-up; walking for 20–30 minutes; 5–10-minute cool-down) at 70%–90% of maximal heart rate.	DPA (Lunar, Lunar Radiation) at L2–L4.
Lord and colleagues (21)	RCT that included 138 subjects assigned to either an exercise (n = 67; age = 70.8 ± 5.0 years) or control (n = 69; age = 71.0 ± 4.9 years) group.	42 weeks of exercise performed 2× per week for approximately 60 minutes per session (5-minute warm-up, 35–40 minutes of aerobic exercises [activities for balance, hand-eye and foot-eye coordination], strengthening exercises, 15 minutes of stretching, and 5–10 minute cool-down).	DEXA (Lunar DPX, Lunar Radiation) at L2–L4.
Martin and Notelovitz (22)	RCT that included 55 postmenopausal women assigned to a 30-minute exercise group (n = 20; age = 60.3 ± 7.8 years), 45-minute exercise group (n = 16; age = 57.8 ± 7.1 years), or control (n = 19; age = 56.7 ± 6.9 years) group.	52 weeks of treadmill exercise performed 3× week for either 30 or 45 minutes per session at 70–85% of maximal heart rate. Each session included a 3–5-minute warm-up and cool-down at 60% of maximal heart rate.	DPA (Lunar DP3, Lunar Radiation) at L2–L4.

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Table 1. Characteristics of Bone Mineral Density Studies (gm/cm^2) in Which IPD Were Provided for Postmenopausal Women at the Lumbar Spine (*Continued*)

Study	Design/Subjects	Exercise Intervention(s)	BMD Assessment
Prince and colleagues (23)	RCT that included assignment of 63 postmenopausal women to a calcium and exercise (n = 35; age = 62.4 ± 4.8 years), or calcium only (n = 28; age = 63.2 ± 4.8 years) group.	104 weeks of weight-bearing exercise performed 2× week for approximately 60 minutes per session. Subjects were also asked to walk another 2 hours per week at 60% of peak heart rate for their age.	DEXA (QDR-1000, Hologic, Waltham, MA) at L1–L4.
Pruitt (24), Pruitt and colleagues (25)	CT that included 24 postmenopausal women assigned to either an exercise (n = 15; age = 53.6 ± 4.1 years) or control (n = 9; age = 55.6 ± 2.9 years) group.	36 weeks of strength training consisting of 13 exercises performed 3× week at 50%–60% of 1RM for 1 set of 10–12 repetitions for the upper body and 10–15 repetitions for the lower body.	DPA (Lunar DP3, Lunar Radiation) at L2–L4.
Ryan and colleagues (26)	CT that included 28 postmenopausal women assigned to either a weight loss (n = 15; age = 63.4 ± 5.7 years) or exercise + weight loss (n = 13; age = 61.3 ± 4.8 years) group.	24 weeks of aerobic exercise (treadmill jogging) performed 3× week for up to 35 minutes per session at 50 to >70% of $\dot{V}O_{2max}$. Each session included a 10-minute warm-up and cool-down period.	DEXA at L2–L4.

Notes: IPD = individual patient data; BMD = bone mineral density; CT = controlled trial; RCT = randomized controlled trial; DPA = dual-photon absorptiometry; DEXA = dual-energy x-ray absorptiometry; MHRR = maximal heart rate reserve; RM = repetition maximum. Study by Prince also included placebo and milk powder group but for comparison purposes, these groups were not included in our analysis. Only subjects who completed the study and for which BMD data were available are reported in the designs/subjects section; number of subjects reported as $\overline{X} \pm SD$. Bone density assessment limited to bone mineral density measures in g/cm^2.

greater in the exercise versus control groups. No statistically significant differences between exercise and control groups were observed for any other continuous or categorical variables.

Primary Outcomes

As can be seen in Table 4, there was an increase in lumbar spine BMD in the exercise groups and a decrease in the control groups. The mean difference between the two groups was 0.013 ± 0.079 g/cm^2, 95% CI = 0.007–0.019. These changes were equivalent to an approximate 2% benefit in lumbar spine BMD (exercise, +1%, control, −1%). The ANOVA results in Table 5 show a statistically significant main effect difference between group and an interaction between group and test. Pairwise comparison tests for the Group × Test interaction revealed a statistically significant increase in final versus initial BMD for the exercise groups (t = 2.464, p = .014), a statistically significant decrease in final versus initial BMD for control groups (t = −3.051, p = .002), and greater initial as well as final values for exercise groups compared to control groups (initial, t = 2.544, p = .011; final, t = 3.320, p = .001). Results were similar when each study was deleted from the model once. For the exercise groups, larger increases in lumbar spine BMD were associated with assessment of BMD using DEXA versus DPA (r = −0.126, p = .018, 95% CI = −0.227–−0.022). For control subjects, larger decreases in lumbar spine BMD were associated with younger age (r = 0.170, p = .002, 95% CI = 0.064–0.272), taller stature (r = −0.109, p = .048, 95% CI = −0.215–−0.005), absence of hormone replacement therapy (r = 0.152, p = .005, 95% CI = 0.047–0.254), assessment of BMD using DPA versus DEXA (r = −0.287, p = .000, 95% CI = −0.381–−0.187) and nonrandomized versus randomized controlled trials (r = 0.172, p = .001, 95% CI = 0.067–0.273). No other statistically significant or clinically relevant relationships were observed for the exercise or control groups. Finally, no statistically significant differences in lumbar spine BMD were found when we compared the 13 studies that included IPD (ES = 0.366 ± 0.423, 95% CI = 0.131–0.600) with the 19 studies that did not include IPD (ES = 0.219 ± 0.430, 95% CI = 0.059–0.379; Q_b = 1.184, p = .277).

Secondary Outcomes

No statistically significant main effects or interactions were found for body weight, calcium intake, or vitamin D intake.

Discussion

The primary purpose of meta-analysis is to reach some general conclusions about a body of research. The overall results of this study suggest that exercise helps to in-

Table 2. Initial Characteristics of Subjects for Continuous Variables

Variable	n	Exercise $\overline{X} \pm SD$	n	Control $\overline{X} \pm SD$	Significance t (p)	CI (95%)
Age (y)	340	63.9 ± 7.4	335	64.5 ± 7.4	−0.92 (.357)	−1.64 to 0.59
Height (cm)	329	158.9 ± 6.9	327	158.2 ± 7.0	1.18 (.239)	−0.43 to 1.71
Body Weight (kg)	340	65.1 ± 12.3	330	64.1 ± 13.0	1.04 (0.299)	−0.91 to 2.94
Postmenopause (y)	156	13.0 ± 9.9	147	17.3 ± 11.8	−3.46 (.001)*	−6.78 to −1.86*
Calcium (mg)	193	926.9 ± 394.0	195	834.7 ± 350.6	2.44 (.015)*	17.79 to 166.64*
Vitamin D (IUs)	55	195.9 ± 215.4	62	161.5 ± 132.4	1.05 (.294)	−30.27 to 99.13

Note: CI = confidence interval; IUs = international units.
*Statistically significant.

Table 3. Initial Characteristics of Subjects for Categorical Variables

Variable	Exercise *n* (%)	Control *n* (%)	χ_2 (*p*)
Cigarette Smoking	25 (9.9)	33 (12.7)	1.04 (.307)
Alcohol Consumption	130 (52.2)	121 (47.5)	1.14 (.285)
Estrogen/Progesterone Use	24 (6.9)	18 (5.4)	0.65 (.419)
Previous Fractures (any site)	61 (37.4)	62 (41.6)	0.57 (.450)
Race (white)	259 (94.1)	238 (91.2)	1.78 (.182)

Note: Results limited to studies that reported data for each variable.

Table 5. ANOVA Summary Table for Lumbar Spine BMD (General Linear Model)

Source of Variation	*df*	SS	*MS*	*F*	*p*	Partial η^2
Group	1	0.834	0.834	8.685	.003*	0.012
Error (Group)	697	66.962	0.096	—	—	—
Test	1	0.000	0.000	0.199	.656	0.000
Test × Group	1	0.001	0.001	15.232	.000*	0.021
Error (Test)	697	0.670	0.001	—	—	—

Note: SS = sum of squares; *MS* = mean square; Group = exercise vs control; Test = initial vs final.

*Significantly different, $p \leq .05$.

crease and maintain lumbar spine BMD in postmenopausal women. This supports our previous meta-analytic work of summary means and lumbar spine BMD (4,5), but is in contrast to our more recent meta-analytic work using IPD in which we found no statistically significant difference in femoral neck BMD (27). Although these are important findings, the clinical importance of an approximate 2% benefit, especially as it relates to fracture risk, cannot be elucidated at this time. However, although beyond the scope of this study, the increased strength, balance, and ambulatory skills that may be realized from a regular program of exercise may also help reduce the risk of falling and suffering subsequent fractures (28). Although we were unable to identify specific exercise programs for optimizing lumbar spine BMD, it would appear plausible to suggest that one adhere to the recent National Institutes of Health Consensus Statement that recommends participation in regular exercise, especially resistance and high-impact activities (28).

Our finding that larger decreases in BMD in the control groups were associated with younger age is not surprising given the fact that bone loss is most rapid during the early postmenopausal years (29). In addition, the observed association between the absence of hormone replacement therapy and greater decreases in lumbar spine BMD was also not surprising because hormone replacement therapy is an established therapeutic intervention for preserving BMD among postmenopausal women (28). However, we can offer no biological explanation regarding the observed association between greater decreases in lumbar spine BMD and taller stature. This is especially because it is generally believed that shorter women are considered more osteoporotic than taller women. Given this currently held notion, caution is warranted in the interpretation of this finding. Indeed, it may be that our observed association was nothing more than the play of chance given the large number of statistical tests that were conducted in our study.

Meta-analysis, like any other type of review, is limited by the availability of data and the limitations of the included studies. Thus, in addition to making the best of the existing data and trying to reach some overall conclusions regarding a body of research, it is also the meta-analyst's responsibility to identify areas of weakness to provide directions for future research.

For example, because we were unable to categorize the different types of exercise interventions, we would suggest that future researchers provide a better description of their exercise programs, especially as it relates to the forces employed during the exercise intervention. Consequently, exercise programs that provide optimal benefits to lumbar spine BMD can be recommended.

We were surprised that data on calcium intake were available for only 56% of the subjects included in this analysis. Because calcium intake is important for maintaining and/or increasing BMD in humans, it would seem reasonable to suggest that data on calcium intake be assessed and reported. In addition, because vitamin D intake is also important for the absorption of calcium and data on vitamin D intake were available for only 17% of the subjects included in this analysis, the assessment and reporting of this information also appears warranted.

Although white, non-Hispanic women are disproportionately affected with osteoporosis and low bone mass, the effect on other races is also significant. For example, the National Osteoporosis Foundation has reported that approximately 10% of black women older than 50 years have osteoporosis, and 29% have low bone mass. Additionally, 16% of American-Indian and Hispanic women aged 50 and older have osteoporosis, and 36% have low bone mass (30). Because approximately 93% of the subjects in this study were white and the responses to exercise in relation to BMD may vary by race, it is recommended that future studies include women from other ethnic groups.

Because data on the number of years that the subjects were postmenopausal were available for only 43% of the subjects included in this analysis, future research needs to include this type of information because it may be a potential confounder in relation to exercise-induced changes in lumbar spine BMD in postmenopausal women.

The fact that the vast majority of studies included in our meta-analysis were published in refereed journal articles may have led to an overestimate of the benefits of exercise on BMD at the lumbar spine because there is a tendency for authors to submit, and editors to publish, studies that yield statistically significant and positive results, i.e., publication bias (10).

Table 4. Lumbar Spine BMD Results (g/cm^2)

Group	*n*	Initial ($\bar{X} \pm SD$)	Final ($\bar{X} \pm SD$)	Difference ($\bar{X} \pm SD$)	CI (95%)
Exercise	355	0.991 ± 0.221	0.996 ± 0.224	0.005 ± 0.043	0.001 ± 0.009*
Control	344	0.948 ± 0.218	0.941 ± 0.218	−0.007 ± 0.045	−0.012 ± −0.002*

Note: CI = confidence interval.

*Statistically significant.

For both exercise and control subjects, greater decreases in lumbar spine BMD were associated with assessment of BMD using DPA versus DEXA. Because DEXA is generally considered to be a more valid assessment of BMD and is currently the most common method used to assess BMD at the lumbar spine, the results from studies using DEXA may be more valid. The finding that greater decreases in lumbar spine BMD were associated with nonrandomized versus randomized trials suggests that randomized trials may yield more valid results.

Although the above-described associations are interesting, they should be viewed with caution for the following reasons: (i) they may have been nothing more than the play of chance given the large number of statistical tests that were conducted, (ii) we were unable to examine for potential interrelationships between variables because of missing data, and (iii) the associations accounted for only a small proportion of the total variance.

In conclusion, the results of this IPD meta-analysis suggest that exercise improves and maintains lumbar spine BMD in postmenopausal women.

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