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One-Year Psoas Training Can Prevent Lumbar Bone Loss in Postmenopausal Women: A Randomized Controlled Trial

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Summary. On the premise that bone response to exercise is locally controlled [1], we conducted a randomized trial to evaluate the effects of a 1-year training of psoas muscles (treatment group: TG) versus a 1-year training of deltoid muscles (control group: CG) on the lumbar trabecular bone mineral density (TBMD). TBMD was measured with computed tomography scan. Seventy-eight subjects were included and 67 completed the study. Intention to treat analysis revealed no significant change in TBMD from 0 to 12 months. Data analysis in the 67 remaining women, including both assiduous and nonassiduous subjects, revealed greater bone loss in CG than in TG although the difference was not significant. Similar analysis in a subgroup of subjects who performed the exercises assiduously (TG: n = 23, CG: n = 26) showed that the mean bone loss of all four vertebrae from 0 to 12 months was significantly greater in the CG (-8.87 ± 12.75 mg/cm^3, mean ± SD) than in the TG (0.14 ± 11.21 mg/cm^3, mean ± SD, $P = 0.01$). These results suggest that continuous 1-year psoas training can prevent lumbar bone loss in postmenopausal women and support the hypothesis of local action of physical activity.

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Key words: Bone mass – Bone density – Osteoporosis – Muscle training – Exercise.

A spate of reports from cross-sectional studies and prospective exercise studies suggests the benefit of physical activity on bone mass [2]. Regular exercise could be a useful prophylactic modality to deter bone loss in postmenopausal women. Prospective studies in exercising subjects have shown promising results [3–6]. However, many questions remain: Should local or general exercises be recommended [7–12]? Is it necessary to perform vigorous exercises, and what is the limit to avoid contrary effects such as stress fractures [13, 14]? What is the length of exercise program necessary to obtain a beneficial effect on bone mass [15, 16]? A long-term exercise program that is easy to perform and specific to the part of the skeleton where the enhanced bone density is needed has seldom been proposed, and few randomized trials to determine the effects of specific exercises on lumbar bone mineral density (BMD) have been reported [17].

Based on the concept that bone response to exercise is locally controlled [1, 18–20] and a previous personal study suggesting that this local mechanism could be the repeated traction exerted by the muscle attachments [21], we evaluated the benefit of a single series of psoas muscle exercises, repeated daily during a 12-month period, on the lumbar vertebral body bone mass in postmenopausal women. A similar exercise program with a muscle not related to the lumbar spine served as control.

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Methods

Subjects

A group of 89 healthy postmenopausal Caucasian women who volunteered to participate in a cross-sectional study [21] were invited to participate in a 1-year exercise intervention trial. They were all recruited from the membership of a pension fund for retired public construction workers (Caisse Nationale de Retraite des Ouvriers du Bâtiment et des Travaux Publics). As part of the cross-sectional study, they had a lumbar computed tomography (CT) scan to study the relationship between cross-sectional muscle area and trabecular bone mineral density (TBMD) of the lumbar vertebrae.

All subjects were postmenopausal for 6 ± 3 years (1–12 years) and were 54 ± 3 years of age (mean ± SD). They had previously completed a health questionnaire documenting the main factors related to bone metabolism. They did not receive any medication known to affect bone mineral content (estrogen or estrogen-like compounds, corticosteroids, fluoride salts, diphosphonates, or calcitonin). They had no history of metabolic bone disease, irregular menstruation, or prolonged bed rest. They all had a lateral X-ray view of the spine showing no osteoporotic fracture. Height and weight were recorded.

Dietary Intake and Customary Physical Activity

Food intake for 1 week was recorded by each woman to evaluate the amount of calcium intake in milligrams per day. They did not take supplements or fortified foods.

Vocational and avocational activities were recorded and served to divide the subjects roughly into two groups. The women spending most of their work time seated were classified as the sedentary work group and the others as the active work group. Those practicing at least 3 hours per week of sport or strenuous spare time activities were classified in the active avocational activities group and the others in the sedentary group. This classification was not used to block for randomization.

All the women received similar instructions regarding the maintenance of customary patterns activity and were asked not to change their diets during the trial.

Fig. 1. Example of right psoas training: 60 flexions of about 30° range of each hip with a sandbag weighing 5 kg on the knee are performed in 2 or 3 sessions daily.

Study Design and Physical Activity Program

The study was a single site, randomized, controlled trial designed to compare the effects on the lumbar vertebral TBMD after 1 year of training of both psoas muscles (active exercise) and training of both deltoids (control exercise) during the same period. During an opening meeting, the trial was discussed, the procedure of randomization was explained, both exercises (exercise supposed to be active and control exercise) were shown and taught. Seventy-eight women were enrolled in the long-term exercise program and accepted randomization and the additional CT scan after 1 year. After a random assignment, they received the material necessary to perform the exercise at the end of the meeting. The following program was assigned to the treatment group: subject in sitting position with a sandbag weighing 5 kg on the knee; 60 flexions of each hip, in two or three sessions, daily for 1 year. The lumbar curve was maintained in extension during the exercises (Fig. 1). The knee was lifted so as to limit the hip flexion to about 30° range in order to prevent hip or lumbar pains.

The program assigned to the control group was as follows: subject in sitting position with a sandbag weighing 1 kg in each hand; 60 abductions of both arms, in two or three sessions, daily for 1 year. The arms were kept straight during the lift and the abduction limited to about 60° range in order to prevent shoulder pains. There was no instruction concerning the duration of each session.

The study was started simultaneously in the two groups, 3.6 ± 2.5 months after the first CT scan for all the randomized women, without difference between the two groups. Each subject was contacted monthly by telephone to enhance compliance to the exercise program. The compliance was determined only verbally.

Bone Mineral Density and Muscle Measurements

The TBMD of L1, L2, L3, and L4 vertebrae was measured by quantitative computed tomography (QCT, Elscint 2400) and expressed in mg/cm^3. The coefficient of variation of this method is 2–5% [22].

We did not measure strength directly as the purpose of the exercise program under evaluation was not particularly to strengthen the psoas but to exert regular pulling forces on the vertebral bodies. However, all women had already had a cross-sectional area and a density measurement of the psoas in the previous study, so these measurements were repeated at the time of the TBMD measurement. The cross-sectional area of the psoas was obtained at L3 level on a section plane crossing halfway up the third vertebral body, perpendicular to the axis of the vertebrae and expressed in mm^2. The muscle limits were drawn on the videoscreen using a joy stick marker. Muscle density measurement in Hounsfield units (HU) was obtained at the same level. The radiologist who performed both the initial and the second CT scan was blinded to the randomization.

Data Analysis

The mean TBMD of L1, L2, L3, and L4, and the mean value of the four vertebrae were calculated in each group. The results are expressed as mean ± SD in mg/cm^3. The difference between the mean value of baseline and of 1-year follow-up was compared between TG and CG using Student's-*t*-test (PCSM Software). A *P* value less than 0.05 was considered significant.

Results

Subject Compliance

Eleven women withdrew from the study but were not lost to follow-up. They were distributed as follows: In the TG, one women moved and was living far from Paris, one had hip pains, and four found the protocol to be too constraining. In the CG, three women stopped because of shoulder pain, one because of back pain, and one considered the protocol too constraining. Nevertheless, we made an "intention to treat" data analysis in all the women who had been randomized except the five women who did not undergo a second CT scan (three in TG and two in CG).

However, considering the purpose of this study, the most interesting data involved the 67 women who underwent two CT scans and who performed their exercises, even irregularly, during the trial. Forty-nine of them (23 in TG, 26 in the CG) performed their exercises assiduously at least 5 days per week over the year and were evaluated as a subgroup of regular performance (55% of the 89 women initially proposed for the study).

The daily total time to perform the 120 flexions varied from 15 to 20 minutes.

Baseline Characteristics

Baseline characteristics are summarized in Table 1. There is no significant difference between the TG and the CG in all variables.

Bone Mineral Density

The mean TBMD of the four studied lumbar vertebrae in all the randomized women except those lost to the second CT scan was as follows: in the TG, 113.45 ± 40.74 mg/cm^3 (mean ± SD) before treatment and 111.96 ± 40.74 mg/cm^3 after 1 year; in the CG, 127.54 ± 37.15 mg/cm^3 before treatment and 122.95 ± 34.56 mg/cm^3 after 1 year. The mean

Table 1. Baseline characteristics, TBMD values, and morphological psoas values[a] of the randomized population

	Psoas-trained group n = 39	Deltoid-trained[c] n = 39	*P* value[b]
Age (years)	57.4 ± 2.9	56.4 ± 2.5	NS 0.14
Duration since onset of menopause (years)	7.1 ± 2.8	5.8 ± 2.7	NS 0.08
Height (cm)	156.6 ± 5.2	155.7 ± 4.9	NS 0.5
Weight (kg)	60.9 ± 9.3	64.7 ± 11.3	NS 0.15
Sedentary profession (%)	56%	56.5%	NS
Active avocational activities (%)	34%	33%	NS
Ca intake (g/day)	0.621 ± 0.453	0.595 ± 0.434	NS 0.82
Smokers	3	2	NS
TBMD (L1–L4) (mg/cm^3)[d]	114.26 ± 40.42	125.25 ± 36.77	NS 0.18
Psoas cross-sectional area (mm^2)	605.26 ± 131.5	659.23 ± 180.83	NS 0.15
Psoas density (HU)	49.04 ± 7.44	46.08 ± 7.37	NS 0.09

NS denotes not significant ($P > 0.05$)
[a] Values are means + SD
[b] Student's *t* test was used to compare the values
[c] Control group
[d] Mean trabecular BMD obtained by QCT in the four studied lumbar vertebrae

TBMD loss was greater in the CG (-6.09 ± 12.77 mg/cm^3) than in the TG (-0.96 ± 15.63 mg/cm^3) but the difference was not significant ($P = 0.14$).

Table 2 shows the mean TBMD changes between baseline values and 1 year values in the 67 women who completed the trial (CG: n = 33, TG: n = 34). Bone loss was always greater in the CG than in the TG, and the difference approached statistical significance for the four vertebrae together ($P = 0.09$).

Table 3 summarizes the baseline values of TBMD and morphological psoas characteristics in the 49 women of the regular performance group (TG: n = 23, CG: n = 26). The data indicate that randomization generated the two groups comparable in all variables including age, duration since menopause, height, weight, level of activity, and calcium intake.

Table 4 shows the mean TBMD and morphological changes in psoas characteristics between baseline values and 1-year values. Bone mass loss of the four vertebrae together was significantly greater in the CG than in the TG ($P = 0.01$). Data analysis in each vertebra always revealed more bone loss in the CG than in the TG, with a significant difference only at the L2 and L3 levels. Changes in psoas area and density did not differ significantly between the two groups.

Table 2. Changes from 0 to 12 months in lumbar TBMD in 67 women who completed the study[a]

	Psoas-trained group (n = 34)	Deltoid-trained group[c] (n = 33)	*P* value[b]
TBMD L1 (mg/cm^3)	−5.01 ± 16.18	−5.66 ± 11.92	NS (0.85)
TBMD L2 (mg/cm^3)	−2.91 ± 14.48	−9.20 ± 12.91	NS (0.08)
TBMD L3 Δ (1 an-J0) (mg/cm^3)	−4.71 ± 14.09	−8.91 ± 13.27	NS (0.23)
TBMD L4 (mg/cm^3)	−7.98 ± 12.82	−8.98 ± 16.08	NS (0.79)
TBMD (L1–L4)[d] (mg/cm^3)	−0.57 ± 1.38	−7.05 ± 12.55	NS (0.09)

NS denotes not significant ($P > 0.05$)
[a] Values are means + SD
[b] Student's *t* test was used to compare the values
[c] Control group
[d] Mean trabecular BMD obtained by QCT in the four studied lumbar vertebrae

Discussion

This study is the first randomized controlled trial to show a positive effect on the lumbar TBMD of a single series of exercises performed daily during 1 year in postmenopausal women.

Although most physicians and researchers agree that physical activity should generally be recommended and is a basic principle of prevention of bone loss, few studies have been devoted to establishing an exercise program that is spe-

Table 3. Baseline values of TBMD and morphological psoas characteristics in the group of women who performed the exercises assiduously[a]

	Psoas-trained (n = 23)	Deltoid-trained[c] (n = 26)	*P* value
TBMD L1 mg/cm^3	115.59 ± 40.77	129.13 ± 32.26	NS[b] 0.20
TBMD L2 mg/cm^3	110.13 ± 37.89	126.85 ± 34.13	NS 0.11
TBMD L3 mg/cm^3	107.10 ± 38.53	120.98 ± 39.94	NS 0.22
TBMD L4 mg/cm^3	106.00 ± 39.57	125.73 ± 40.56	NS 0.09
TBMD (L1–L4)[d] mg/cm^3	107.75 ± 38.09	124.62 ± 37.23	NS 0.12
Psoas cross-sectional area mm^2	581.74 ± 124.60	632.62 ± 181.46	NS 0.27
Psoas density HU	48.79 ± 7.79	48.52 ± 6.15	NS 0.89

[a] Values are means + SD
[b] Student's *t* test was used to compare the values. NS denotes not significant ($P > 0.05$)
[c] Control group
[d] Mean TBMD obtained by quantitative computed tomography in the four studied lumbar vertebrae

Table 4. Changes from 0 to 12 months in lumbar TBMD and morphological psoas characteristics in the group of women who performed the exercises assiduously[a]

	Psoas-trained group (n = 23)	Deltoid-trained group[c] (n = 26)	*P* value
TBMD L1 (mg/cm^3)	−1.17 ± 14.92	−7.15 ± 9.56	NS[b] 0.11
TBMD L2 (mg/cm^3)	0.24 ± 14.17	−9.71 ± 14.17	0.02
TBMD L3 (mg/cm^3)	−1.95 ± 13.82	−11.28 ± 12.75	0.02
TBMD L4 (mg/cm^3)	−4.57 ± 11.27	−11.10 ± 16.31	NS 0.12
TBMD (L1–L4)[d] (mg/cm^3)	0.14 ± 11.21	−8.87 ± 12.75	0.01
Psoas cross-sectional area (mm^2)	13.48 ± 134.78	29.73 ± 158.56	NS 0.71
Psoas density (HU)	−1.87 ± 7.21	−5.15 ± 7.54	NS 0.14

[a] Values are means + SD
[b] Student's *t* test was used to compare the values. NS denotes not significant ($P > 0.05$)
[c] Control group
[d] Mean TBMD obtained by quantitative computed tomography in the four studied lumbar vertebrae

cific to vertebral bodies where enhanced bone density is needed and that is simple enough to be followed for a long period. Furthermore, it is likely that the main reasons for conflicting opinions on the influence of physical activity on bone mass are the confusion in definition of physical activity and the small number of prospective randomized studies that could avoid the methodological basis of cross-sectional, retrospective, or uncontrolled studies [5, 16, 23].

The present study was based on the premise that physical activity, to be effective in skeletal maintenance for postmenopausal women, should involve mainly the muscles attached to the bones to be stimulated. Therefore, training of psoas muscles was considered to be active on lumbar body mass and training of deltoids was considered a control exercise. The results suggest that long-term training of psoas muscles with a simple series of daily exercises can reduce the loss of lumbar TBMD in postmenopausal women and strongly support the assumption that physical activity acts on bone remodeling mainly through a local mechanism.

Lumbar bone mass loss in all the randomized women as well as in the group of women who did not withdraw from the study and who had a second CT scan was less important in the TG than in the CG although the difference was not significant. However, in the subgroup of women who performed assiduously the exercises for 1 year, the difference was significant. It can be assumed that the difference in bone mineral content changes observed after 1 year of follow-up between the two groups was related only to the exercise of the psoas as the baseline values of the main parameters known to affect normal bone metabolism were similar in both groups and the women did not change their customary vocational and avocational activities or their dietary intake during the trial.

The data observed in the subgroup of regular performance imply that to effectively prevent bone loss in lumbar vertebral bodies, psoas training should be persistent and prolonged over an extended period. However, even in this subgroup, we did not observe significant changes in cross-sectional area or in density measurements of psoas muscles after 1 year of training. It is possible that the hip flexion strength was not adequate to induce morphological changes in psoas muscles of older women [24] but was sufficient to have an effect on bone mass. Indeed, although previous studies suggested that stress magnitude has a greater effect on bone mass than the number of loading cycles [1, 25, 26], repeated mild muscle contractions could be also effective provided their strength is sufficient to exert pulling forces on bony attaches. We opted for a 5 kg strength of hip flexion in this hypothesis.

The evolution of the lumbar TBMD in the control group does not support the theory of a systemic effect of physical activity as supported by some studies [3, 11]. Indeed, the rate of observed bone loss (about 4%) was similar to that reported in earlier studies [27]. It can be argued that long-term deltoid training is not sufficient to release humoral factors capable of having general effects on bone remodeling. On the other hand, most of the studies that reported a possible systemic effect were not prospective or utilized physical activity which simultaneously involves several parts of the skeleton [3, 11, 28, 29].

Psoas muscles are mainly inserted on the lateral surfaces of the first four lumbar vertebrae bodies and secondary on the inferior half of T12 and the superior half of L5. The maximum pulling forces exerted at the L2 and L3 levels could explain the more significant results observed on these two vertebrae in our study (Fig. 2). The mechanism by which muscle contraction is transduced into biological signals lead-

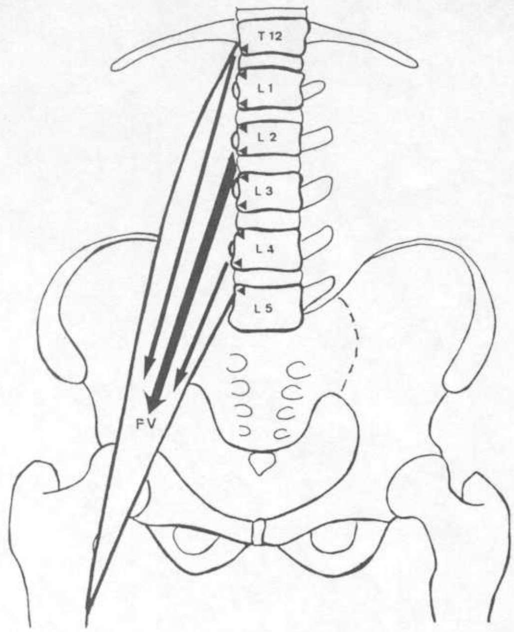

Fig. 2. Antero-posterior view of the lumbar vertebral column and the pelvis showing the attachment sites of the psoas muscle on the vertebral bodies (▲). The main force vector (FV) corresponds to the fascicles attached on L2 and L3.

ing to bone remodeling is not clear. Pulling forces directly exerted on the bone could increase fluid flows in underlying bone and streaming potentials. They could also induce a local piezoelectric effect [30]. Whatever the mechanism, it can be assumed that exercises should involve the muscles attached to the bones to be stimulated.

Further investigations should be carried out to confirm our results and to improve compliance to psoas training. Only 55% of all the women initially included in the trial fully completed the planned training program. This rate could be considered rather good compared with compliance in some long-term drug trials. However, because our population had already been selected on the basis of a previous study and was encouraged by telephone every month, the level of compliance of these women cannot be transposed to the general population. Future studies to optimize psoas training for minimizing postmenopausal bone loss in lumbar vertebrae should perhaps evaluate less constraining programs, for example, shorter daily training.

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