Short-Term Adapted Physical Activity Program Improves Bone Quality in Osteopenic/Osteoporotic Postmenopausal Women

S. Tolomio, A. Ermolao, G. Travain, and M. Zaccaria

Background and aims: It is known that people affected by osteopenia/osteoporosis can benefit from an adequate amount of physical activity, counteracting the progressive loss of bone and muscle mass caused by aging. Moreover, there is increasing evidence that exercise has positive effects on bone structure. The aim of our study was to evaluate the effects on bone tissue and muscular strength of a short-term exercise program in osteopenic/osteoporotic postmenopausal women. Methods: Forty-nine osteopenic/osteoporotic postmenopausal women were divided into 2 groups: exercise and control. All subjects underwent 2 evaluations: before and after a training period. Bone quality was assessed by phalangeal quantitative osteosonography, and maximal strength of leg extensor muscles was also evaluated. The experimental group participated in a specific supervised 20-week physical activity program that included aerobic, balance, and strength training. Results: After the training period, all bone parameters and lower-limb maximal strength were significantly improved in the exercise group (P < .05), whereas no significant changes were observed in the control group. Conclusions: Our study showed that a broad-based training protocol, lasting 20 weeks, can improve leg strength and bone quality parameters—main determinants of fall and fracture risk, respectively.

Keywords: exercise program, bone health, phalangeal osteosonography

Regular physical activity has been demonstrated to play an essential role in maintaining or improving density and mechanical strength of bones.1–3 Most researchers suggest that short bouts of high-resistance exercises induce greater benefits on bone mineral density (BMD), although this effect seems to be mainly site specific4–6; however, the optimal duration, intensity, frequency, and protocol of physical activity able to increase BMD have not yet been determined. Furthermore, BMD can only partially explain the effect of exercise on skeletal...
bones; in fact, exercise seems to also influence bone microarchitecture, elasticity, and resistance. It is known that dual X-ray absorptiometry provides only a quantitative measurement of bone, whereas ultrasound methods can measure something different from bone mineral content and density that is generally defined as bone quality. Only a few studies have employed this method to assess the effect of exercise on bone tissue.

The aim of this study was to evaluate if a supervised, short-term, adapted exercise program (20 weeks) can induce detectable improvements in bone ultrasound parameters of osteopenic/osteoporotic postmenopausal women.

**Materials and Methods**

**Subject Recruitment**

We contacted 110 postmenopausal women who were daughters of osteoporotic fractured women and offered an osteoporosis phalangeal osteosonography screening with preventive purpose. Eighty-four women who showed a $t$-score $<-1.0$ SD were asked to take part in the study. Sixty-four of them accepted and gave their informed consent to participate. By a simple randomization they were then divided into 2 groups, experimental and control; 36 women were assigned to the experimental group and 28 to the control group.

The larger size of the experimental group was chosen to prevent a loss of statistical power resulting from subject dropout. Criteria of inclusion were the following:

1. postmenopausal women (age between 50 and 70 years),
2. diagnosis of osteopenia or osteoporosis ($t$-score determined by ultrasounds $<-1.0$ SD),
3. lack of any diseases that affect bone metabolism,
4. no previous skeletal fractures, and
5. lack of any contraindication to perform physical activity.

During the training period (20 weeks), we registered a dropout of 7 subjects in the experimental group owing to health or personal problems, and 8 subjects in the control group did not agree to repeat the tests at the end of the study. No significant differences were observed between the subjects who dropped out and the subjects who remained in the study.

Anthropometric characteristics of the subjects are presented in Table 1.

Drug therapy was not the same for all subjects, and some of them were not taking any drugs. However, no significant differences were present between groups. Table 2 shows the drug consumption in each group.

The experimental group followed a specific supervised activity program including balance, aerobic, and strength training (3 times per week for 20 weeks). The lessons were conducted by a certified instructor with a specialization in adapted physical activity and took place both in a clinical setting (hospital rehabilitation unit) and in a gym. All subjects were instructed to maintain their physical activity habits, drug therapy, and usual diet until completion of the study.
Evaluation Before and After the Training Period

All subjects underwent 2 different evaluations:

1. Bone quality was assessed by phalangeal quantitative osteosonography (DBM Sonic 1200, IGEA S.r.l., Carpi [MO], Italy) performed at the fingers of the non-dominant hand. The DBM Sonic 1200 measures the amplitude-dependent speed of sound through the bone (Ad-Sos, expressed in m/s), and the ultrasound bone profile score (UBPS), an index calculated from the ultrasound graphic trace, gives a quantitative evaluation of the ultrasound signal characteristics. Both of these parameters are related to bone density and elasticity.\(^1\)

All the evaluations were carried out always by the same experienced operator in a single-blind design. The short-term precision of the instrument was determined on a series of repeated measurements performed on 2 subjects, in terms of coefficient of variation (CV%) for Ad-Sos measures. The coefficient we obtained (0.61%) was similar to other previous studies.\(^12\),\(^13\) Subjects who participated in the study were daughters of fractured osteoporotic women and were evaluated for preventive purpose. Because osteosonography is a good, fast, noninvasive and not expensive screening tool, we decided to administer only this kind of evaluation. Subjects who showed poor bone qualities (eg, low t-score) were then advised to also take a conventional bone assessment (eg, dual X-ray absorbiometry).

2. Maximal strength production of knee extensor muscles (1-RM) was estimated by an isotonic leg-extension machine (Leg-extension R.O.M., with power control system, Technogym S.p.A., Gambettola [FC], Italy). The 1-RM was calculated from the 10-RM max using a prediction equation [1-RM = 1.554 × (10-RM weight) − 5.181].\(^14\) 10-RM was taken as the heaviest weight that each subject was able to lift 10 times through a complete range of motion. The 10-RM was achieved by increasing the load by 5 kg after each successful set of lifts (10 lifts per set) until the maximum load sustainable for 10 lifts was obtained. Subjects had a 5-minute rest interval between each weight increment.

Training Protocol

The program consisted of 60 supervised exercise sessions (3 times a week over a period of 20 weeks) including the following:

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### Table 1 General and Anthropometric Characteristics of Subjects\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>29</td>
<td>20</td>
</tr>
<tr>
<td>Age (y)</td>
<td>59.4 ± 4.3</td>
<td>57.7 ± 4.7</td>
</tr>
<tr>
<td>Age at menopause (y)</td>
<td>48.2 ± 5.8</td>
<td>49.2 ± 3.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70.0 ± 9.8</td>
<td>69.8 ± 10.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.0 ± 4.3</td>
<td>161.1 ± 5.3</td>
</tr>
</tbody>
</table>

\(^a\) Data are expressed as mean ± SD.
Table 2  Drug Consumption Within Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Ca – D3  n (%)</th>
<th>Bisphosphonates  n (%)</th>
<th>Raloxifen  n (%)</th>
<th>HRT  n (%)</th>
<th>No therapy  n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental (n = 29)</td>
<td>6 (20.7)</td>
<td>8 (27.6)</td>
<td>1 (3.4)</td>
<td>2 (6.9)</td>
<td>12 (41.4)</td>
</tr>
<tr>
<td>Control (n = 20)</td>
<td>4 (20.0)</td>
<td>5 (25.0)</td>
<td>1 (5.0)</td>
<td>1 (5.0)</td>
<td>9 (45.0)</td>
</tr>
</tbody>
</table>

Abbreviation: HRT, hormone replacement therapy.
• two 60-minute sessions consisting of callisthenic/isometric exercises and exercises with dumbbells, Thera-Bands, and balls aimed to improve joints range of motion, overall strength, balance, and aerobic capacity and
• one 45-minute session consisting of a combination of aerobic endurance and strength exercises (using different ergometers and weight machines).

Each 60-minute exercise session included a warm-up phase lasting about 20 to 25 minutes (walking, stretching, small jumps), followed by a 30-minute training phase (with exercises for large and small muscle groups). During the last 5 to 10 minutes, subjects were instructed to cool down with stretching, breathing, and postural exercises.

The progression of the exercise volume was obtained by a graded increase of the exercise intensity and number of repetitions and series, starting after the fifth week of training.

Each 45-minute exercise session included circuit training, consisting of 6 bouts of exercise lasting 5 minutes each: (I) treadmill, (II) leg extension, (III) arm ergometer, (IV) horizontal leg press, (V) bike, and (VI) lat-machine.

Aerobic training (I, III, V) consisted of low-intensity exercises performed at a preset intensity during the first period (speed of 3.5 km/h for treadmill, power of 60 W for arm ergometer, and power of 80 W for bike) and then adapted to the individual level of capacity and rate of perceived exertion (RPE Borg Scale). Subjects were instructed to perform the exercises between levels 10 and 13 (accordingly to the 6 to 20 RPE Scale).

With respect to strength exercises (II, IV, VI), throughout the training period, subjects were instructed to increase the number of repetitions or the load lifted with the aim of getting a progressively higher amount of exercise volume during each 5-minute strength exercise bout but without exceeding the RPE intensity of 10 to 13 (6 to 20 RPE Scale).

Because it is known that exercise has a site-specific bone-mineral-content increasing effect, all the strength exercises were selected to avoid directly loading the phalanges. However, handling dumbbells, Thera-Bands, and balls could have induced an unintentional load.

**Statistical Analysis**

Baseline characteristics of the experimental and control groups were compared by Student *t*-test. Two-tailed analysis of variance was used to compare the differences among the groups in the changes in bone and muscle strength measurement data and to assess the efficacy of the training period on the experimental group with respect to the control group; the paired *t*-test was used to analyze the longitudinal changes within the groups. The alpha value was set at *P* < .05.

Statistical analysis was performed using the Statistical Package for Social Sciences, SPSS version 11.0 for Windows. The results are expressed as the mean value ± SD.
Results

Basal values and drug therapy consumption did not show any significant difference among groups (Tables 1 and 2).

As shown in Table 3, after the training period, in the experimental group we observed an improvement of all measured parameters in comparison with baseline values and in comparison with controls.

Ad-Sos, the most important parameter to evaluate bone quality, significantly increased after the training period only in the experimental group (from 1956.2 ± 80.0 m/s to 1977.8 ± 74.4 m/s; \( P < .05 \)).

The UBPS improved in all groups, but significantly only in the experimental group, increasing from 31.7 ± 18.6 to 36.8 ± 21.3 in the experimental group (\( P < .05 \)) and from 33.6 ± 16.8 to 36.5 ± 17.2 in the control group.

In the experimental group, \( t \)-scores significantly improved (from –2.4 ± 1.1 to –2.1 ± 1.1; \( P < .05 \)), whereas the control group did not show any significant change.

Finally, after the training period, the maximal strength of knee extensor muscles significantly improved in the experimental group (from 44.1 ± 11.0 kg to 52.7 ± 9.5 kg; \( P < .05 \)), whereas no significant changes were observed in the controls.

Discussion

This study showed that a planned training period of supervised adapted physical activity (lasting 20 weeks) significantly improved bone quality (assessed at hand phalanges) and leg strength in osteopenic/osteoporotic postmenopausal women.

Our physical activity protocol consisted mainly of aerobic and resistance training but also included joint mobility, coordination, and balance exercises. Several papers demonstrated that these exercise modalities are useful in maintaining and improving bone mass and are fundamental in preventing falls.18–22

Several studies18,23; see 1 for a review have considered the efficacy of physical activity in osteoporotic patients, but, at present, only few studies have evaluated the effects of a training period on bone quality.24,25

The purpose of our study was to evaluate the effects of a supervised, short-term, adapted physical activity program on bone tissue quality in postmenopausal women with osteopenia/osteoporosis.

We investigated bone quality by phalangeal osteosonography, whose parameters appear significantly correlated both with BMD and with qualitative properties of bones, such as microarchitecture, resistance, and elasticity. All these parameters have been demonstrated to be predictors of fracture risk independently of BMD.26–29

To date, only Vainionpaa24 and Ay,25 using calcaneal broadband ultrasound attenuation, have evaluated the effects of a training period on bone quality in
### Table 3 Results Before (1) and After (2) the 20-Week Training Period\(^a\)

<table>
<thead>
<tr>
<th>Group</th>
<th>Ad-Sos</th>
<th>UBPS</th>
<th>t-score</th>
<th>Leg extension(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Experimental</td>
<td>1956.2 ± 80.0</td>
<td>1977.8 ± 74.4</td>
<td>31.7 ± 18.6</td>
<td>36.8 ± 21.3</td>
</tr>
<tr>
<td></td>
<td>−2.4 ± 1.1</td>
<td>−2.1 ± 1.1</td>
<td>44.1 ± 11.0</td>
<td>52.7 ± 9.5</td>
</tr>
<tr>
<td>Control</td>
<td>1962.6 ± 84.3</td>
<td>1968.9 ± 74.6</td>
<td>33.6 ± 16.8</td>
<td>36.5 ± 17.2</td>
</tr>
<tr>
<td></td>
<td>−2.3 ± 1.2</td>
<td>−2.3 ± 1.2</td>
<td>41.4 ± 8.0</td>
<td>37.9 ± 6.8</td>
</tr>
</tbody>
</table>

Abbreviations: Ad-Sos, amplitude-dependent speed of sound; UBPS, ultrasound bone profile score.

\(^a\) Data are expressed as mean ± SD.

\(^b\) Maximal leg extension strength.

\(^c\) \(P < .05\).
postmenopausal women, showing a significant improvement in the exercise group compared with a control group.

Despite a shorter duration of our protocol in comparison with other studies,\textsuperscript{18,22,23–25} we obtained a significant increase of all bone parameters (Ad-Sos, UBPS, and $t$-score) in the exercise group. These early positive effects of our training on these parameters may be interpreted more as a qualitative adaptation of bone structure than a quantitative improvement of BMD that generally occurs after a more prolonged period of training.\textsuperscript{18,22} Furthermore, because the osteosonography was performed on the proximal phalanges of the hand, our results could be interpreted as a site-specific mechanical stimulus of strength exercises involving the hands. This also represents an important limitation of our study because many articles have already shown that exercise has a site-specific effect on bone.\textsuperscript{16,17}

However, owing to the multidimensional (involving the whole body) exercise protocol, the positive effect showed on finger bone quality could be observed also at different bone sites.

Finally, isometric leg strength has been demonstrated to be an important predictor in determining the risk of falls in the elderly.\textsuperscript{30,31} The improvement we observed in strength evaluation demonstrated the effectiveness of our training protocol: maximal leg strength significantly increased in the exercise group, whereas it showed a slight but not significant reduction in the control group. Considering that a progressive loss of strength affects all aging populations, these data confirm the importance of a specific training protocol in postmenopausal women with a low BMD and the ability of the protocol to not only improve bone quality but also to reduce the risk of falls.

**Conclusions**

In conclusion, we can state that in a group of postmenopausal women, a supervised, multidimensional exercise program improved bone quality, evaluated at the finger, in a relatively short period of time. In addition, the study confirms that people affected by osteopenia/osteoporosis can benefit from an adequate amount of physical activity to counteract the progressive loss of bone and muscle mass that is the result of aging.

**References**


