Effects of an exercise program on respiratory function, posture and on quality of life in osteoporotic women: a pilot study

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Abstract

Objectives To investigate the effects of an exercise program on respiratory function, thoracic kyphosis, tolerance to exercise and quality of life in women with osteoporosis.

Design Pilot observational study.

Setting Department of Physiotherapy, Federal University of Sao Carlos, Brazil.

Participants Fourteen women with densitometric diagnosis of osteoporosis in the spine.

Interventions An exercise program comprising of three sessions per week, lasting 1 hour each, over an 8-week period. Each session incorporated: 5 minutes of stretching exercises, including the lower limb and upper limb muscles; 15 minutes of posture exercises; 20 minutes of walking; 15 minutes of exercises to improve the strength of respiratory muscles and a 5-minutes, cool-down and relaxation.

Main outcome measures Respiratory function evaluation, submaximal exercise tolerance test measurement of the thoracic kyphosis angle, and the Osteoporosis Assessment Questionnaire (OPAQ) to measure the quality of life at baseline and at 8-week follow-up.

Results At follow-up, increases of between 12% and 23% in respiratory pressures were noted. The results also suggest an increase of 13% in submaximal exercise tolerance and a small increase of approximately 5% in the magnitude of thoracic curvature. The value of the OPAQ for this group of subjects is questionable. Sample size calculations based on the results of this pilot study are provided.

Conclusions After an 8-week exercise program, benefits to the fitness of the participants were observed. The results suggest that exercise may have a role in the management of this group of patients. The outcome measures, with the possible exception of the OPAQ, and the protocol used in this pilot study would be feasible for a definitive study. Further research is recommended in a sufficiently powered study and should include an appropriate control group.

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Keywords Osteoporosis; Kyphosis; Exercise tolerance; Physical activity; Quality of life

Introduction

Osteoporosis is a clinical syndrome in which bone mass is lower than expected for individuals of a given age and race, resulting in bone weakness and increased susceptibility to fractures [1]. Osteoporosis represents a severe health threat to elderly people and it has recently been recognised as a major public health problem [2].

The main clinical manifestation is the increased risk of fractures [2,3]. Vertebral fractures are the most frequent and often involve the mid-thoracic, lower-thoracic and lumbar vertebrae [1]. These fractures result in wedging and compression of the vertebrae, causing alterations in the physiological spinal curvatures, such as scoliosis, kyphoscoliosis and an accentuation in the degree of thoracic kyphosis [4].

Acccentuated thoracic kyphosis alters the shape of the thoracic cage, increases the antero-posterior diameter of the
thorax, reduces the distance between xiphisternum and pubis, and alters the position of the rib cage so that it surrounds the abdominal cavity. The spinal deformity and alterations in the rib cage cause a decrease in rib mobility and an impairment in the mechanics of the respiratory system, placing the respiratory muscles at a mechanical disadvantage and resulting in a decrease in respiratory muscle strength [5]. These changes are reported to be responsible for the impairment in respiratory function found in osteoporotic subjects [1,6,7]. Culhan et al. [1] found a significant reduction in vital capacity and inspiratory capacity in elderly women with osteoporosis, compared with normal subjects of the same age.

It is thought that exercise has an important role in management of the physical and psychological consequences of osteoporosis. The results of a previous study suggested that exercise may maintain, or even increase, bone mass, flexibility and muscle force; thus improving balance, gait and quality of life in these subjects [2].

The increase in the degree of thoracic kyphosis can be considered as one of the most important clinical manifestations of osteoporosis. Improvements in posture may reduce the level of pain, lessen the risk of falls and increase respiratory function. Consequently, an improvement in respiratory function and aerobic fitness may affect physical activity levels and result in improvement in quality of life. Little is known about the effects of exercise on posture and respiratory function in osteoporotic patients.

The purpose of this study was to determine the effects of a general physical exercise program on respiratory function, posture, submaximal exercise capacity and quality of life in women with osteoporosis.

Methods

This work constituted a pilot study. Subjects were recruited by telephone from a population of more than 250 osteoporotic women of the Institute of Rheumatic Diseases in Brazil. From these, 26 women, with a densitometric diagnosis of osteoporosis in the spine, showed an interest in participating.

Criteria for inclusion were: 65 years of age or older, caucasian, non-smoking, sedentary (having not performed any type of exercise for at least one year) with no previous fractures and a minimum of 75% attendance on the exercise program. Subjects who had pulmonary diseases, neurological disorders or medical conditions which would prevent them from exercising were excluded. Written consent was obtained from all subjects.

Upon each subject’s arrival in the laboratory, the purpose and procedures involved in the study were explained and data were obtained. Pre- and post-intervention tests were carried out at the same time of the day.

Physical evaluation

Demographic data including weight, height, resting heart rate, systolic blood pressure and diastolic blood pressure were recorded.

Pulmonary function tests

Spirometry

The standard protocol recommended by the American Thoracic Society [8] was adopted. A Masterscop spirometer with a reported error of ± 5% (Jaeger gmBh Co., Wuerzburg, Germany) was used to obtain vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and maximal voluntary ventilation (MVV). During the test, the subjects were seated and used a nasal clip. Each test was performed three times and the best result of the three trials for each subject was used in the analysis. One pulmonary function laboratory technician conducted all tests.

Respiratory muscle force

Maximal inspiratory pressure (MIP) was recorded to provide a measure of inspiratory muscle strength. Maximal expiratory pressure (MEP) was measured to give an indication of expiratory muscle strength [9,23]. These measurements were obtained from a device with a cylindrical plastic mouthpiece adaptor connected to a pressure gauge (~ 300+300 mmHg). A hole of 2 mm in diameter was drilled in the mouthpiece adaptor, designed to prevent the subject from sustaining pressure with their cheeks [23]. Wang et al. [10] reported that the error for spirometry and respiratory pressure assessment was within ±5%. Calibration of the mechanical gauge was checked before the test to ensure that the error did not exceed ±5%.

The physiotherapist demonstrated the correct maneuver and patients were given a minimum of three practice attempts to reduce any learning effects. The subject was seated and, used a nasal clip. To obtain a measurement of MIP, participants were instructed to exhale slowly and completely to residual volume, then to seal their lips around the mouthpiece and inhale with as much force as possible. After 3 seconds, the subject was instructed to stop the inspiration. To obtain a measure of MEP, participants were instructed to inhale slowly to total lung capacity, press the mouthpiece against their lips and to exhale as hard as possible [9,23]. Each test was performed five times. For analysis, the best of the five readings was used.

Submaximal exercise capacity

The 6-minutes walk test (6-MWT) is a submaximal test often used to measure physical function in chronic obstructive pulmonary disease subjects and elderly people. This is a quick, inexpensive and reliable test to measure submaximal exercise capacity and it is a good marker of response to therapeutic interventions [11,12]. Performed in a corridor...
50 m long, participants were given standardised instructions to cover the greatest distance possible in 6 minutes. The physiotherapist walked 1 m behind the participant during the test. At the end of the 6-minute period, the distance walked was measured.

Measurement of thoracic kyphosis

The degree of kyphosis was measured with a photometric technique validated by Vieira et al. [13]. This is a non-invasive technique, based on fixation of cutaneous markers on the spinous processes of the vertebrae, which allows measurement of the degree of spinal curvature. The cutaneous markers consist of an acrylic base in the middle of which is fixed a perpendicular, metallic shaft. Markers, when fixed on the spine, allow measurement of the inclination of the spinous processes. The vertebrae were located by palpation [14] and a cutaneous marker was fixed to the spinous processes of the 7th cervical vertebrae (C7) and the 12th thoracic vertebrae (T12). A photographic image of each participant, in the sagittal plane, was recorded and analysed using the software AutoCAD 2000 (Autodesk, San Francisco, USA). Parallel lines were projected from the shaft markers of C7 and T12 which allowed the degree of thoracic kyphosis to be computed.

Using this photometric technique, Vieira et al. [13] reported significant correlation between repeated measures of lumbar lordosis in male subjects with both intra-observer and inter-observer coefficients of $r^2 = 0.998$. However, the limitations of these forms of statistical analysis should be recognised. Furthermore, this study compared the measurements of lumbar lordosis during lumbar spine movement in neutral, $15^\circ$, $30^\circ$ and $45^\circ$ of flexion. Measurements were made using the photometric technique and compared with those obtained using an electromiographometer. The coefficients of variation between the techniques were: 2% (neutral), 7% ($15^\circ$), 3% ($30^\circ$) and 2% ($45^\circ$). No statistically significant differences were demonstrated between the two techniques, and the two sets of measurements were found to correlate with a coefficient of $r^2 = 0.999$. The author concluded that the photometric technique has an overall error of ±4%.

Quality of life

The Osteoporosis Assessment Questionnaire (OPAQ), adapted for the Brazilian population [15], was selected. The OPAQ is a self-administered questionnaire comprising 79 questions in 18 sections that measure aspects of physical function, psychological status, symptoms and social interaction. The 18 items fall into four categories: flexibility, capacity to perform daily activities, level of pain and level of tension/anxiety.

There are five possible responses to each question (0–4), representing the frequency with which the symptom is experienced or the level of difficulty experienced in performing an activity [16]. In the categories ‘flexibility’ and ‘capacity to perform daily activities’, a response of 4 indicated the most favourable response and 0 the least favourable response (Table 1). For categories relating to ‘level of pain’ and ‘level of tension’, 0 indicated the most favourable response and 4 the least favourable. The scale has been validated by Driusso et al. [16]. Responses were summed for each section and the median score calculated. The evaluations were repeated twice, once before the exercise program and then immediately after the end of the 8-week training program.

Exercise program

The program comprised of three one-hour sessions per week, over 8 weeks. Heart rate was measured at the beginning of the session and at 20-minute intervals thereafter to monitor the level of activity.

Each session incorporated:

- 5 minutes of general warm up: stretching exercises of lower and upper limb muscles.
- 15 minutes of exercises to improve posture: emphasising back extensor muscle strength [17]. Subjects lifted a backpack with an intensity determined using the 1 repetition maximum test (1-RM). The program increased progressively each week, as back muscle strength increased [18]. The 1-RM test is determined by the maximal weight that can be lifted once through full range. Participants were informed about the purpose of the test and correct performance of the exercise. With the participants lying prone, a weight of 5 kg was put in a backpack. The participant attempted to extend their trunk and was asked about the difficulty of lifting the weight. Weights were added gradually, in 1-kg increments, until the participant reached their 1-RM. If this was not reached by the fourth attempt, the test was interrupted and repeated 2 days later to avoid fatigue of the back muscles. The subjects worked with 30% of their 1-RM in the backpack and were instructed to do this exercise 10 times during each session.

| Table 1 | Scoring for questions on the capacity to perform daily activities and level of tension/anxiety |
|---|---|---|---|---|---|
| | Every day | Almost every day | Some days | Few days | Next |
| In the last month |
| Capacity to perform daily activities |
| How often were you able to cook by yourself? | 4 | 3 | 2 | 1 | 0 |
| How often were you able to buy food by yourself? | 4 | 3 | 2 | 1 | 0 |
| Level of tension/anxiety |
| How often did you feel you are losing balance? | 0 | 1 | 2 | 3 | 4 |
| How often did you feel falling? | 0 | 1 | 2 | 3 | 4 |
while in the prone position [17]. Every week, the 1-RM was re-evaluated and the load was increased accordingly.

- 20 minutes of aerobic exercises (walking): subjects worked at their own pace but were encouraged to work between 60 and 70% of their predicted maximum heart rate [2,19].
- 15 minutes of respiratory muscle exercises: to strengthen the respiratory muscles, weights were placed on the abdomen, offering resistance to diaphragmatic movement and a stimulus for training [20]. The exercise comprised of three sets of contractions with 10 repetitions. The intensity of the exercise was based on the 1-RM [18]. Participants had a weight of 2 kg placed on their abdomen. They were instructed to make an inspiratory effort (abdominal expansion) and were asked about the difficulty of lifting the weight. The weights were adjusted individually, in 1-kg increments, until the participant reached their 1-RM. Participants worked at 60% of their 1-RM in the first and second weeks, 70% of their 1-RM in the third and fourth weeks and 80% of the 1-RM thereafter [18]. Every week the 1-RM was re-evaluated to check progression. Although various pieces of equipment are available to train the respiratory muscles, a simple, low-cost method was selected in preference.
- Sessions finished with a five-minute cool-down period and relaxation exercises.

In this study, the values of the 1-RM for the back muscles and for the inspiratory muscles were not analysed.

**Statistical analysis**

Descriptive statistics are presented for all variables in this study, for baseline characteristics and pre-intervention and post-intervention results. Changes from baseline values were expressed as percentage of baseline scores. Due to small sample sizes and the pilot nature of this study, further inferential analysis was not appropriate.

**Calculation of the likely sample size**

Based on this pilot study, it is possible to calculate the required sample size to detect a clinically relevant difference, should one exist. The mean values and standard deviations of MVV, MIP, MEP and degree of kyphosis were calculated. The following sample size formula was applied [21]:

\[ n = \left( Z_{\alpha/2} + Z_{\beta/2} \right)^2 \sigma^2 / \delta^2 \]

where \( d \) = sample maximum error, \( Z_{\alpha/2} \) = level of confidence and \( \sigma^2 \) = variance.

**Results**

Seven women were excluded from the study: two were smokers and a further five due to asthma. Nineteen women were recruited and commenced the exercise program. How-

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### Table 2

<table>
<thead>
<tr>
<th>Physical characteristics of participants (n = 14)</th>
<th>Mean (S.D.)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>68.7 (2.0)</td>
<td>65–72</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66.5 (6.6)</td>
<td>53–75</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>152.0 (7.7)</td>
<td>144–167</td>
</tr>
</tbody>
</table>

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The results of this pilot study suggest that physical exercise may have a role in improving the range of variables evaluated in this group of patients. However, an adequately powered study is now required to confirm these tentative findings. It is also possible that the improvements noted in respiratory function and the degree of thoracic kyphosis may have contributed to the increase in the distance walked in 6-MWT and...
Table 3
Baseline and post-intervention scores for respiratory function evaluation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Baseline Mean (S.D.)</th>
<th>Range</th>
<th>Post-intervention Mean (S.D.)</th>
<th>Range</th>
<th>Percentage improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC (L)</td>
<td>2.5 (0.5)</td>
<td>2.2–3.3</td>
<td>2.6 (0.4)</td>
<td>2.4–3.8</td>
<td>4</td>
</tr>
<tr>
<td>FVC (L)</td>
<td>1.9 (0.4)</td>
<td>1.5–2.9</td>
<td>2.0 (0.4)</td>
<td>1.7–3.1</td>
<td>5</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>1.8 (0.3)</td>
<td>1.5–2.2</td>
<td>1.9 (0.3)</td>
<td>1.8–2.4</td>
<td>5</td>
</tr>
<tr>
<td>MVV (L/minute)</td>
<td>76.2 (2.4)</td>
<td>65.1–91.5</td>
<td>85.5 (4.5)</td>
<td>70.5–98.5</td>
<td>12</td>
</tr>
<tr>
<td>MIP (cmH2O)</td>
<td>34.2 (3.9)</td>
<td>25.0–55.0</td>
<td>42.1 (3.2)</td>
<td>35.0–65.0</td>
<td>23</td>
</tr>
<tr>
<td>MEP (cmH2O)</td>
<td>33.0 (2.3)</td>
<td>20.0–55.0</td>
<td>40.0 (4.8)</td>
<td>30.0–70.0</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 4
Baseline and post-intervention scores for angle of kyphosis and 6-MWT

<table>
<thead>
<tr>
<th>Variables</th>
<th>Baseline Mean (S.D.)</th>
<th>Range</th>
<th>Post-intervention Mean (S.D.)</th>
<th>Range</th>
<th>Percentage improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of kyphosis (°)</td>
<td>57.3 (14.0)</td>
<td>37–85</td>
<td>54.2 (12.8)</td>
<td>34–79</td>
<td>5</td>
</tr>
<tr>
<td>6-MWT (m)</td>
<td>400 (65)</td>
<td>400–600</td>
<td>546 (60.6)</td>
<td>503–650</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 5
Baseline and post-intervention scores for quality-of-life variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Baseline Median</th>
<th>Range</th>
<th>Post-intervention Median</th>
<th>Range</th>
<th>Percentage improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity to perform daily activities</td>
<td>4</td>
<td>0–4</td>
<td>4</td>
<td>1–4</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>4</td>
<td>0–4</td>
<td>4</td>
<td>0–4</td>
<td></td>
</tr>
<tr>
<td>Level of pain</td>
<td>2</td>
<td>4–0</td>
<td>1</td>
<td>4–0</td>
<td></td>
</tr>
<tr>
<td>Level of tension/anxiety</td>
<td>2</td>
<td>4–0</td>
<td>1</td>
<td>4–1</td>
<td></td>
</tr>
</tbody>
</table>

Table 6
Values for recommended sample sizes based on MVV, MIP, MEP and angle of kyphosis

<table>
<thead>
<tr>
<th>Variables</th>
<th>Number of subjects required per group</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVV (L/minute)</td>
<td>5</td>
</tr>
<tr>
<td>MIP (cmH2O)</td>
<td>12</td>
</tr>
<tr>
<td>MEP (cmH2O)</td>
<td>28</td>
</tr>
<tr>
<td>Angle of kyphosis</td>
<td>65</td>
</tr>
</tbody>
</table>

in the quality of life reported by these patients. Moreover, with the data obtained, it was possible to calculate the likely sample size for a major study.

Frequently, patients with osteoporosis present with an increase in thoracic kyphosis, which can lead to a decrease in pulmonary function, exercise capacity and, ultimately, quality of life [1,17]. Thus the selected variables provide a useful measure of the severity of the effects of this disease.

The differences between pre-intervention scores and post-intervention scores for MVV, MEP, MIP, degree of kyphosis and 6-MWT were greater than the reported error of the evaluation methods used, suggesting that the exercise program was beneficial to the participants in this study.

Although five women were excluded due to lack of attendance, the average attendance of the remainder was high. The participants reported that the exercise sessions were enjoyable and resulted in an improved sense of well-being.

Spirometry and maximal respiratory pressures have been used repeatedly to measure respiratory function and are routine procedures used in pulmonary function laboratories [22,23]. These measures are reliable and adequate to assess the variables proposed and to determine the changes caused by an exercise program [23].

The exercise program incorporated specific respiratory and aerobic exercises. The increases in MVV, MEP, and MIP suggest that during training, the respiratory muscles were sufficiently loaded to induce structural and functional adaptations, improving the respiratory function in these patients. Using weights placed on the abdomen seems to offer sufficient stimulus to the respiratory muscles; however, further work to validate this method is required.

All the participants were considered to have a hyperkyphosis of the thoracic spine, with a mean angle of spinal curvature greater than the 37.1° suggested for subjects with osteoporosis.

After the 8-week exercise program, a decrease in the degree of spinal curvature of 5% was observed. Itoi and Sinaki [17] observed a decrease of approximately 12% in hyperkyphotic post-menopausal subjects, following a program of exercises designed to enhance back extensor muscle strength.

This study demonstrated an increase in values for the 6-MWT, suggesting an increase in submaximal exercise capacity. A learning effect has been found for the 6-MWT, calculated to be 7% of the measured distance, indicating that a practice walk is necessary [24]. In this study, a practice walk was not included and this needs to be recognised as a limitation which should be addressed in a definitive study. However, the increase of 13% (66 m) observed suggested that the improvement was greater than the learning effect indicating a beneficial effect, of the exercise program.

Sanchez et al. [5] reported an increase of 58 m in the 6-MWT in subjects with chronic obstructive pulmonary disease after a respiratory muscle training program, and suggested that this increase is sufficiently large to be considered clinically relevant.
The value of the OPAQ to assess the quality of life in this group of patients is questionable. Participants did not have any difficulty in understanding the questions and showed interest in answering the questionnaire. However, the small changes noted in the index values suggest that the questionnaires may not be sufficiently sensitive to detect change in this group. Further validation work is therefore required in a larger sample. The small reduction in reported level of pain and tension/anxiety is in line with the results of Mitchell et al. [2] and Malmoes et al. [25].

Conclusion

The results of this pilot study cannot be generalised to the osteoporotic population as a whole. However, despite the lack of a control group and the small size of the sample studied, the results suggest that further study is warranted. With the possible exception of the OPAQ, the methods of evaluation were found to be appropriate for measurement of the parameters proposed and preliminary data have been provided to allow sample size calculation for a definitive study. The improvements observed following the 8-week training program, which is low cost and easily performed, suggest that it may have beneficial effects in this population.

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References