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ORIGINAL ARTICLE

The association between osteoporosis and static balance in elderly women

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Abstract
Summary This study aimed at answering the question: do people with high bone loss have greater postural instability? Groups were separated into group 1: women with normal bone mineral density, group 2: women with osteopenia, and group 3: women with osteoporosis. The balance was evaluated in four upright postural situations. Osteoporosis group had greater oscillation in the anteroposterior displacement in all situations compared to control group and the greatest mediolateral displacement in all situations compared to other groups.
Introduction It is not known whether the presence of osteoporosis can be considered a factor aggravating the postural control. This study aimed at answering the question: do people with high bone loss have greater postural instability?
Methods This study was divided into three groups: group 1 (n=20) consisting of women with normal bone mineral density, group 2 (n=20) women with osteopenia, and group 3 (n=20) women with osteoporosis. All the participants were submitted to evaluation of the balance using the Polhemus system in four upright postural situations.
Results Osteoporosis group had greater oscillation in the anteroposterior displacement in all situations compared to control group. The osteoporosis group also showed the greatest mediolateral displacement in all situations compared to other groups.
Conclusion The results suggest that osteoporotic women had the worst balance, possibly due to the more pronounced body changes compared to non-osteoporotic women.

Keywords Bone mineral density · Elderly women · Postural control · Static balance

Introduction

The ability to maintain a stable posture is important to perform functional activities such as walking, sitting down, and standing up, as well as volitional movements coordinately, which is essential for daily tasks. However, there is a postural oscillation over time that is strongly associated with an increase in the incidence of falls. Data from the Ministry of Health [1] show that 28,459 elderly persons had died in Brazil between 1979 and 1995 due to falls. Additionally, in February 2000, the inpatient mortality rate from falls was 2.58%.

The rate of falls among the elderly is high and the resulting fractures and severe lesions lead to a partial or total decrease in their daily activity performance and autonomy, causing them to stay in bed and to become disabled [2]. Carvalho has cited in his study that 30% of elderly women have at least one episode of fall annually,

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with fracture occurring in 3–5% of the cases [3]. The presence of osteoporosis is of great concern for elderly persons presenting with postural instability who not only have a high risk of fractures, but also more pronounced postural changes [4]. Based on the increased risk of fall resulting from the aging process and in an effort to better understand the relationship of bone mineral density on the complex functioning of the postural control, the following question was raised: do people with high bone loss have greater postural instability?

Methods

The study population consisted of community-dwelling elderly. Sixty sedentary women over 60 years old were recruited. This research study was approved by the Research Ethics Committee of the Ribeirão Preto Faculty of Medicine. The exclusion criteria included women presenting with history of bone fractures (previously investigated through X-ray), diabetes mellitus, peripheral neuropathies, cardiovascular diseases, vestibulopathies, and neurological problems.

The women were divided into three groups according to the World Health Organization criteria: group 1 (n=20) was formed by women with normal bone mineral density (BMD) in the vertebrae (T-scores greater than −1 standard deviation [SD]), group 2 (n=20) consisted of women with low bone density (osteopenia; T-scores between −1 and −2.5 SD), and group 3 (n=20) consisted of women with osteoporosis (T-score lower than − 2.5 −SD). The measurement of BMD was done by using dual-energy X-ray absorptionmetry.

The static balance tests were performed in all subjects. Balance was evaluated by using the Polhemus system (POLHEMS ® 3 SPACE ISOTRAK II, Colchester, Canada) equipped with electromagnetic sensors. This system, consisting of three perpendicular coils (22.9 mm×28.3 mm× 15.2 mm) connected to an amplifier, is based on both emission and detection of magnetic fields. Through the signals obtained by the three sensor coils, one can have x-y-z orientation and their angles in relation to the transmitting coils. Then, the Polhemus system allows deviations on planes "x" (anteroposterior), "y" (mediolateral), and "z" (vertical) to be measured.

Static balance was evaluated in four upright postural situations: (1) standing on a fixed wooden platform with eyes open for 90 s; (2) standing on a fixed wooden platform with eyes closed for 90 s; (3) standing on a foam surface (7-cm thickness) with eyes open for 90 s; and (4) standing on a foam surface with eyes closed for 90 s. The anteroposterior and mediolateral displacement were analyzed.

During evaluation, the transmitting coil was positioned by using a support near the subject (60-cm distance) and a sensor coil was attached to the seventh cervical vertebra as shown in Fig. 1.

Fig. 1 Positions of sensor coil on the seventh cervical vertebra (*1*) and transmitting coil (*2*)

Statistical analysis

By using the Shapiro–Wilk normality test and the Levene's test for variance homogeneity, it was observed that the subjects' mean values regarding all variables meet the presumptions required for applying univariate and multivariate analyses. As a result, one multivariate analysis of variance (MANOVA) and three analysis of variance (ANOVA) analyses were performed. The MANOVA assessed the group factors (control, osteopenia, and osteoporosis subjects), platform (fixed or unstable), and vision (eyes open or closed), and these two latter factors were treated as a repeated measurement. The dependent variables assessed by MANOVA were anteroposterior and mediolateral body displacements. ANOVA was used to assess whether the groups had anthropometric similarity. Three analyses of variance had groups as factors. In the first ANOVA, age was the dependent variable, whereas weight and height were the dependent variables in the second and third analyses of variance, respectively. Univariate analyses and post hoc Tukey's test were performed when needed. All statistical analyses were conducted by using the SPSS software (SPSS for Windows, V10.0–SPSS Inc., USA) at a significance level of 0.05.

Table 1 Means and standard deviations for age (years), body weight (kg), and height (cm) for all control, osteopenic, and osteoporotic subjects. ANOVA revealed no group effect on age [F(2,59)=3.08, $P>0.05$], weight [F(2,59)=1.68, $P>0.05$], or height [F(2,59)=0.37, $P>0.05$]

	Age	Weight	Height
Control	66.2 (±4.7)	67.3 (±8.1)	156.6 (±5.0)
Osteopenic	67.5 (±4.6)	62.6 (±10.2)	155.6 (±7.0)
Osteoporotic	70.0 (±5.4)	69.0 (±15.0)	154.8 (±6.0)

Results

Table 1 presents the means and standard deviations for age, weight, and height regarding the three groups of subjects. ANOVA analyses showed no group effect on age [F(2,59)=3.08, $P>0.05$], weight [F(2,59)=1.68, $P>0.05$], or height [F(2,59)=0.37, $P>0.05$].

Body displacement

Figures 2 and 3 show the values for anteroposterior (Fig. 2) and medio-lateral (Fig. 3) body displacements in control, osteopenic, and osteoporotic groups regarding fixed platform with eyes open, fixed platform with eyes closed, unstable platform with eyes open, and unstable platform with eyes closed. MANOVA analysis revealed effect on group [Wilk's lambda=0.71, F(4,56)=5.19, $p<0.05$], platform [Wilk's lambda=0.60, F(2,56)=41.46, $p<0.05$], and vision [Wilk's lambda=0.72, F(2,56)=10.79, $p<0.05$],

With regard to the anteroposterior body displacement (Fig. 2), univariate analyses showed differences regarding group [F(2,57)=6.85, $p<0.05$], vision [F(157)=21.3, $p<0.05$], and platform [F(1,57)=74.8, $p<0.05$]. Post hoc tests indicated that osteoporotic women have greater body displacement compared to control group in all experimental situations. The subjects of all three groups had increased body displacement in those situations requiring eyes closed and unstable platform.

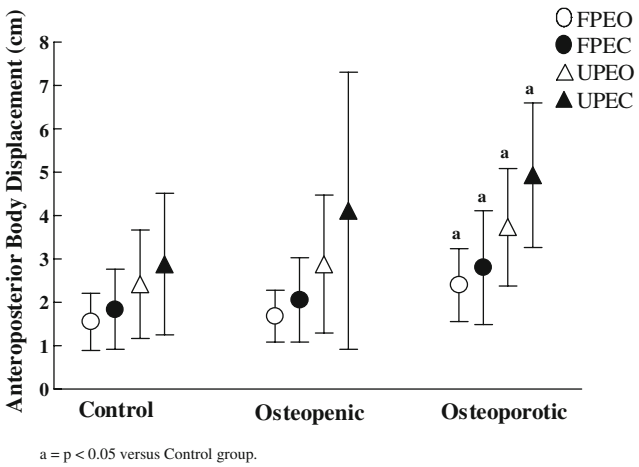

Fig. 2 Means and standard deviations of anteroposterior body displacement for control, osteopenic, and osteoporotic groups regarding fixed platform with eyes open (FPEO), fixed platform with eyes closed (FPEC), unstable platform with eyes open (UPEO), and unstable platform with eyes closed (UPEC). a=$p<0.05$ vs. control group

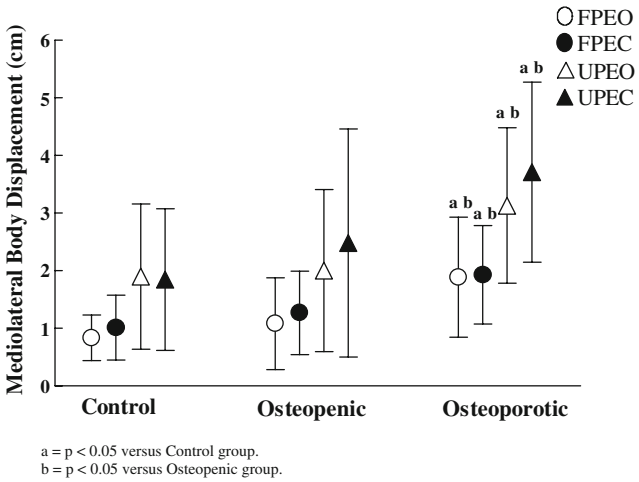

Fig. 3 Means and standard deviations of mediolateral body displacement for control, osteopenic, and osteoporotic groups regarding fixed platform with eyes open (FPEO), fixed platform with eyes closed (FPEC), unstable platform with eyes open (UPEO), and unstable platform with eyes closed (UPEC). a=$p<0.05$ vs. control group; b=$p<0.05$ vs. osteopenic group

With regard to the mediolateral body displacement (Fig. 3), the univariate analyses revealed differences for group [F(2,57)=10.70, $p<0.05$], vision [F(1,57)=8.01, $p<0.05$], and platform [F(1,57)=57.78, $p<0.05$]. Post hoc tests indicated difference between control and osteoporotic groups as well as between osteopenic and osteoporotic groups in all experimental situations. Osteoporotic women had a greater mediolateral body displacement compared to both control and osteopenic groups. The subjects of all three groups had increased body displacement in eyes closed and unstable platform situations.

Discussion

The alterations resulting from the aging process cause changes in the elderly postural control. The postural control depends on the integration of neural and muscular-skeletal systems. These systems have a functional decline over time, thus, directly interfering with the balance and leading to an increase in corporal oscillation in elderly persons [5].

The present study assessed the static balance (anteroposterior and mediolateral displacements) in elderly women with normal bone mineral density, osteopenia (known as low bone mineral density), and osteoporosis.

The results showed that all three groups had oscillations in both anteroposterior and mediolateral directions, mainly in the experimental situations with eyes closed and unstable platform. Increase in postural instability in such situations can be considered a predictive factor for falls among elderly individuals walking in dark or low-light environments and on irregular floor surfaces during AVDs. This demonstrates that integration of visual, vestibular, and proprioceptive systems is important to maintain one's balance. These systems have specific functions: the proprioceptive system provides information about one's perception of where the body is in relation to space; the vestibular system sends information to the central nervous system regarding cephalic movements in relation to spatial positioning, whereas the visual system provides exteroceptive information for modulating motor activity and balance [7, 8]. Also, information from these systems should be matched and constantly selected within the environmental and sensory context and based on the type of expected task so that stability can be achieved [6].

Our results corroborate the findings of previous studies [9–11] showing the influence of sensory systems on equilibrium, since all the subjects taking part of the present study exhibited greater postural oscillation on foam platform compared to fixed platform. Also, this oscillation was greater in situations requiring eyes closed rather than eyes open, that is, the body oscillation increased depending on both difficulties and changes in sensorial information [5].

Our results have shown that, within the same age group, women with osteoporosis had greater anteroposterior displacement in all experimental situations compared to those with normal BMD.

The results regarding mediolateral displacement showed that osteoporotic group had a greater displacement compared to both control and osteopenic groups. No difference was observed between osteopenic and control women.

It is important to point out that although osteoporotic women had exhibited greater mediolateral oscillation in all experimental situations, the osteopenic women had an anteroposterior oscillation similar to that of osteoporotic women in all situations.

Although the aging process impairs the functioning of sensory systems [12], in addition to promoting postural changes and decreasing the muscular forces, which can also interfere with the balance, the results obtained in this study suggest that osteoporotic elderly women may have more pronounced body changes compared to non-osteoporotic women as all three groups of subjects showed no differences regarding age, which was not found to be a factor contributing to the postural instability. Further studies are needed to better elucidate the biomechanical characteristics in women with or without osteoporosis.

According to Lynn et al., osteoporotic women are more likely to fall than the non-osteoporotic ones within the same age group, for the former have greater weakness and impaired postural control [13]. Also, some studies suggest that osteoporotic women have greater muscular weakness mainly affecting the load-bearing muscles (e.g., column extensors muscles) as well as the adductor and abductor muscles of the hip [14, 15]. Perhaps this can explain why the group of osteoporotic women had greater body oscillation, possibly suggesting that bone loss and muscular weakness are associated with more pronounced changes in the body configuration as the skeletal-muscular system is involved as a whole. Besides, the results show that women with osteopenia also have impaired balance and, based on a study by Siris et al. demonstrating that osteopenic women was associated with 1.8-fold higher rate of fracture than women with normal BMD, a careful attention should be paid to this population in order to reduce the risk of falls [16].

The present study has some limitations. For instance, no assessment of both muscular strength and functional limitations (e.g., decrease in the mobility of vertebral column) was performed. These factors can cause impairment of the postural control. Also, no postural evaluation was carried out in order to detect postural deformities that might interfere with the balance.

Conclusions

These results suggest that osteoporotic women have greater balance instability compared to women with normal BMD. Therefore, the presence of osteoporosis seems to interfere negatively with anteroposterior and mediolateral postural control, although osteopenic women showed anteroposterior displacements similar to those of osteoporotic women.

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Conflicts of interest None

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