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Impaired Ability to Perform the Sit-to-Stand Task in Osteoporotic Women

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1. Introduction

The process of aging causes several physiological alterations and body modification in elderly people. These changes include decrease in bone mass and muscular strength, rigidity in joints, and range of movement reduction in addition to changes in the central nervous system such as slow nerve conduction velocity (Deschenes, 2011), co- contraction of antagonist muscles, and alterations in the sensorial systems (visual, somatosensitive, vestibular functions), all contributing for the impairment of postural control and functional activities (Gauchard et al., 2003).

The maintenance of the postural stability is important during functional activities such as sitting down and standing up, walking, as well as for performing volitional movements co-ordinately, which is essential for daily tasks. The increase of postural control system deficit, which is associated to aging, has a strong relation to the risk of falls. In Brazil, data from the Ministry of Health shown that 28,459 elderly persons had died between 1979 and 1995 due to falls and, in February 2000, the inpatient mortality rate for falls was 2.58%.

Changes in postural control and decreased muscle strength and power are important risk factors for falls, especially in the elderly, since there is a reduction in muscle strength of 30-50% between 30 -80 years, especially in the lower limbs (Burke et al., 2010; Janssen et al., 2002).

The reduction in muscle strength occurs due to the reduction in the number and size of muscle fibers. Mainly type II fibers (fast contraction), which are most affected in relation to type I fibers (slow contraction) (Frontera et al., 1991).

The intensity of the muscle fibers loss depends on the degree of physical activity, nutrition, hereditary factor and lifestyle throughout life. In addition to losing in maximum muscle strength due to the aging process, there is also the loss of muscle power (force x speed), leading to a greater impairment in performance of functional activities, which requires agility, such as standing and walking, and increase susceptibility to falls (Marsh, 2000; Hunter et al., 2004).

The sit-to-stand test is a widely used tool in clinical practice because it is easy to apply and it requires simple matters, which are chair (without armrests) and a stopwatch. There are several ways to perform the test, but the way that is most commonly used, is to perform five

repetitions as quickly as possible, where the shorter the time to accomplish this task, the better the performance of the individual (Kim et al., 2010).
The risk of falls is increasing among elderly individuals who have difficulty in standing up from the chair (Campbell et al., 1989; Nevitt et al., 1989), since people with history of falls take more time to stand up from the chair and to stabilize their trunk after achieving the orthostatic position (Cheng et al., 2001). It is known that the action of standing up and sitting down is affected by decreased muscular strength and power, sensorial alterations, balance, and velocity in which this task is performed (Karikanta et al., 2005).
The incidence of falls increases with age and this fact is of great concern among the elderly, particularly among those with osteoporosis who present increased bone fragility, which increases the risk of fractures (Honig, 2010).
However, it is not clear if the osteoporotic women have a greater muscle function impairment compared to women with less bone losses and, consequently, have poorer dynamic postural control, which increases the risk of falls.
The muscle-bone unit has been suggested based on the mechanostatic theory, since muscle contractions promote tension in the bone, with consequent bone modeling activation. Therefore, the increase of muscle mass is also accompanied by increase of bone strength and improvement of bone geometrical characteristics (Hasegawa et al., 2001; Frost, 2003; Fricke & Schoenau, 2007). Also, the positive effect of some physical exercise on the increase of both muscle strength and bone mineral density (BMD) corroborates the relationship between bone and muscular systems.
Following these statements, the increased bone loss is accompanied by an increase of both muscle mass and muscle strength losses. However, based on the muscle-bone unit, the decrease of bone is consequence of both decrease of muscle mass and strength (Hamilton et al., 2010).
Therefore, in women with osteoporosis is expected an impairment during the functional activities performance, as sit-to-stand task, since they require the action of muscular system. The postural control impairment during functional tasks (standing up and sitting down) can make these individuals more susceptible to falls and subsequent fractures. For this reason, it is important to investigate factors that may worsen postural control in order to prevent falls, injuries and to improve the quality of life.

2. Objectives

To evaluate whether osteoporotic women have impaired dynamic balance in relation to those women presenting less bone loss by using the sit-to-stand test.

3. Hypothesis

Women with higher bone loss have greater impairment in postural control, needing to perform a greater flexion of the trunk to perform the sit-to-stand task, as a way of compensate for a probable weakness of the lower limb muscles, and spend more time to perform the test, compared to women with lower bone loss. The bone mineral density (BMD) loss can occur in association with a reduction of muscular capacity, due to the fact that muscular and skeletal systems act as a unique unit. The evaluation of dynamic balance through the sit-to-stand test can be an efficient method to detect the association between bone and muscular systems.

4. Methods

A cross-sectional study, which sixty women were divided into three groups according to the World Health Organization (WHO) classification of osteoporosis: Group 1 (n = 20) consisted of women presenting T score greater than - 1 standard deviation (normal bone mineral density), Group 2 (n = 20) consisted of women presenting T score ranging from -1 and -2.5 standard deviation (osteopenia or low bone mineral density), and Group 3 (n=20) consisted of women presenting T score lesser than -2.5 standard deviation (osteoporosis). For Group 1, the mean age was 65.75 years (± 4.33), mean weight was 64.81 kg (± 6.83), and mean height was 157.0 cm (± 6.0). In Group 2, the mean age was 67.45 years (± 4.57), mean weight was 62.63 kg (± 10.21) and mean height was 156.0 cm (± 7.0). In Group 3, the mean age was 70.0 years (± 5.43), mean weight was 68.97 kg (± 15.01) and mean height was 155.0 cm (± 8.0).

Women presenting vertebral fractures diagnosed by radiographs, diabetes mellitus, peripheral neuropathies, cardiovascular diseases, vestibulopathies, and neurological problems were excluded from this study. All women were sedentary, no smoker and none of them was included in any kind of rehabilitation program.

The participants were selected from the general community and from the Centre of Health at the Ribeirao Preto School of Medicine, FMRP-USP (CSE-FMRP-USP) and affiliated Clinic Hospital. The research study was approved by the Human Research Ethics Committee of the Ribeirao Preto School of Medicine, University of São Paulo (protocol number 1953/2007), with all the volunteers signing a free informed consent before participating in the study.

All the participants were submitted to evaluation of dynamic activity using the Polhemus system, in which the maximum antero-posterior dislocation of the trunk and time spent for practicing the test were evaluated.

The Polhemus system (POLHEMS ® 3 SPACE ISOTRAK II, Conchester, Canada) (Abreu et al.; 2010) was employed for evaluation, which is based on emission and detection of magnetic fields by means of electromagnetic sensors (Figure 1). The emission system comprises three perpendicular coils (55 x 55 x 58 mm) and the detection system is also formed by other three perpendicular coils (2.9 x 28.3 x 15.2 mm), and an amplifier was used to obtain x (antero-posterior), y (medio-lateral), and z (vertical) orientations. The transmitting coil was positioned onto a support that was placed at 60 cm from the subject, whereas the sensory coil was fixed to the seventh cervical vertebra (C7). The equipment precisely measures every trunk movement: the attached transmitting coil emits magnetic fields which are detected by the sensor, considering that the distance between the transmitting and sensory coils is known.

The dynamic activity was evaluated during the sit-to-stand (STS) (Bohannon, 2006) movements five times so that the maximum trunk antero-posterior dislocation and time spent for practicing the test could be obtained. An armless chair with seat height of 43 cm was used for this test. The subject started the test with her both feet on the floor and her arms crossed at the chest level. Then she was asked to perform the sit-to-stand movements five times consecutively as quickly as possible, and the test was concluded when the evaluator asked the subject to remain in the chair (Figure 2).

Analysis of variance (ANOVA) was used for comparison between the groups. According to these statistical models, the residual differences between predicted and measured values have a normal distribution, with zero mean and constant variance. In the situations where such a presumption was not observed, changes in the response were taken into account. Post-hoc Tukey test were performed when needed. This procedure was performed by using the SPSS 16.0.

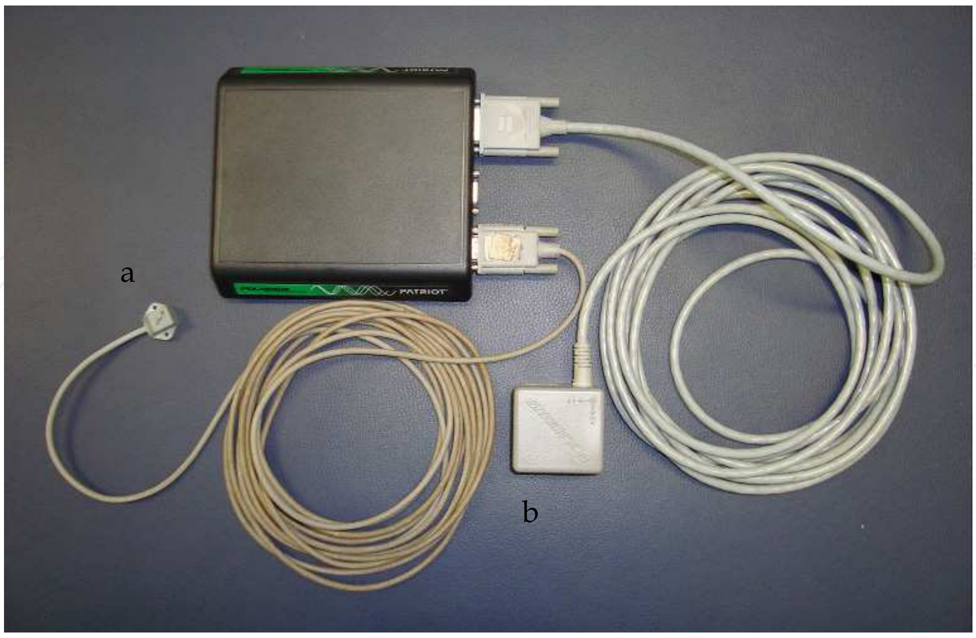
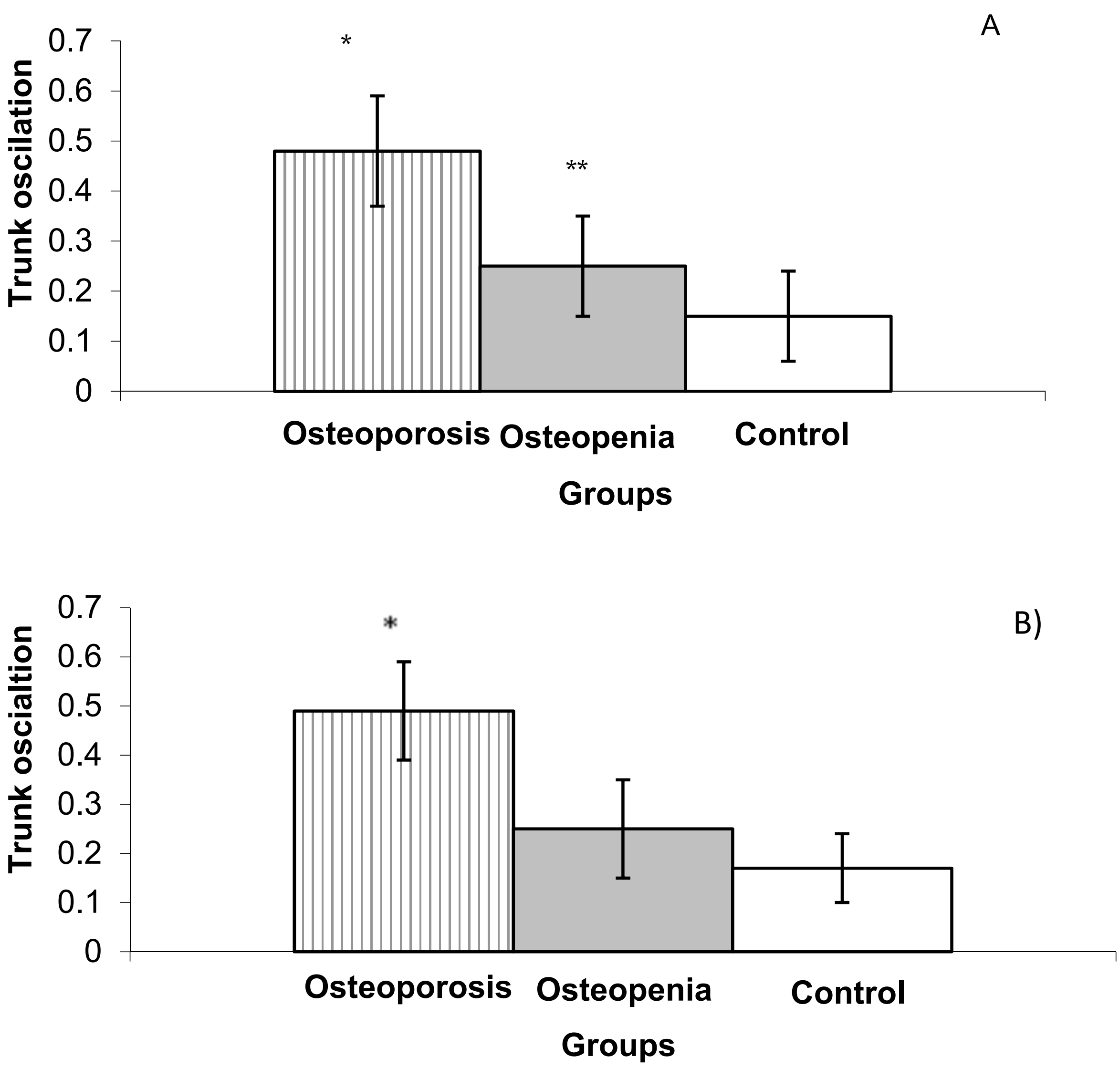


Fig. 1. Illustration of the Polhemus system. a) sensor coil; b) transmitting coil.

Fig. 2. Illustration of initial position for the sit-to-stand test. Arrows indicate the positions of sensor coil on the seventh cervical vertebra and the transmitting coil.

5. Results

The results showed that variables such as weight and height showed no significant differences between the groups ($P > 0.05$), but age was found to be different between the control and osteoporotic groups ($P < 0.01$). For this reason, the variables maximum antero-posterior dislocation (cm) during standing up and sitting down tasks and time (seconds) spent for practicing the test were normalized by age.
Post-hoc Tukey test showed that women with T score lesser than - 2.5 SD (osteoporosis) had greater movement of the trunk during standing up and sitting down tasks compared to other groups of women. Also, women with T score between -1 and - 2.5 SD had greater movement of the trunk in relation to the group of women presenting normal bone mineral density (T score greater than – 1 SD) during stand up from the chair (Figure 3).



*P < 0.05 osteoporosis versus osteopenia and control
** P < 0.05 osteopenia versus control

Fig. 3. Antero-posterior dislocation (cm) during the standing up (A) and sitting down (B) tasks. Values were normalized by age.

The results showed that there were no differences in the time spent to perform the sit-to-stand movements ($P > 0.05$) between the groups (Figure 4).
In the Group 3 (women with osteoporosis), the time spent for performing the STS test was 15.14 ± 4.18 sec (0.22 ± 0.06 sec after normalized by age) and the antero-posterior movements of the trunk during standing up and sitting down tasks were, respectively, 33.03 ± 7.04 cm (0.48 ± 0.11 cm after normalized by age) and 34.15 ± 6.27 cm (0.49 ± 0.10 cm after normalized by age). In Group 2 (women with osteopenia), the overall time spent was 13.34 ± 3.34 sec (0.20 ± 0.07 sec after normalized by age), with antero-posterior movements of the trunk during standing up and sitting down tasks being, respectively, 16.98 ± 11.03 cm (0.25 ± 0.17 cm after normalized by age) and 16.61 ± 11.61 cm (0.25 ± 0.17 after normalized by age). With regard to Group 1 (women with normal BMD), the time spent for performing the STS test was 11.95 ± 2.1 sec (0.18 ± 0.03 sec after normalized by age) and the antero-posterior movements of the trunk were 9.86 ± 9.12 cm (0.15 ± 0.13 after normalized by age) and 10.96 ± 9.74 cm (0.17 ± 0.16 after normalized by age) during standing up and sitting down tasks, respectively.

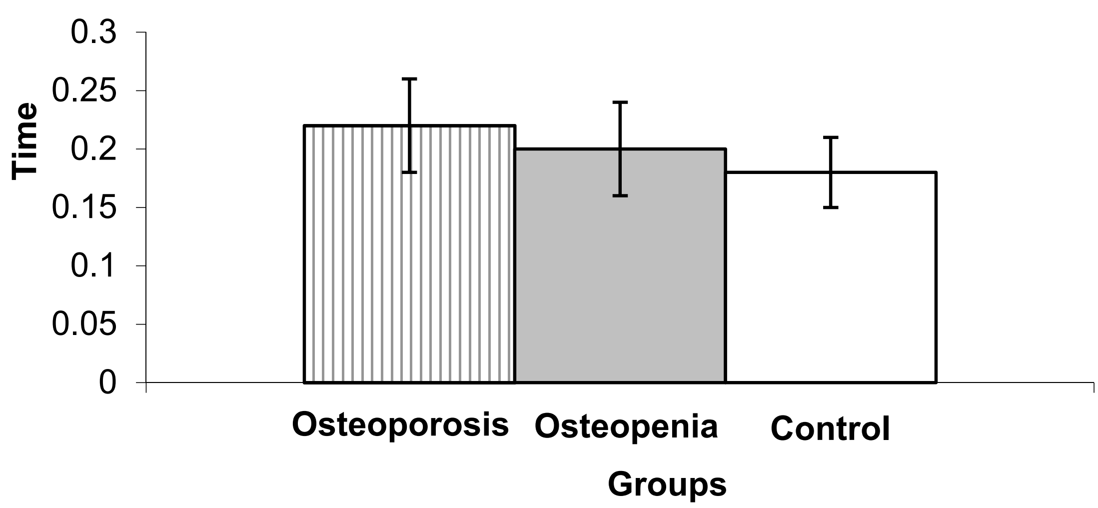


Fig. 4. Time spent (sec) during the sit-to-stand task. Values were normalized by age.

6. Discussion

The aging process is associated to many changes of body function, which include alterations in the postural control during posture maintenance and activities, which interfere directly with balance and lead to an increase in corporal oscillation in elderly persons (Gill et al., 2001).
The postural control system requires the association of perception (of body position and body movement) (Faraldo-García et al., 2011), action (capacity of muscle activation) and cognition (movement planning and execution). In order to have an efficient action it is necessary, besides muscle function, other biomechanical aspects, as adequate range of movement and posture. The muscle deficits can have a negative influence on postural control and functionality, because they decrease the ability to perform functional movement with safety and efficiency which increase the risk of falls (Shumway-Cook &, Woollacott, 2000). Additionally, the decrease of muscle strength and power in elderly persons has a negative impact on the ability to restore the state of balance after external perturbations.

The sit-to-stand (STS) test is easy to apply and it is one of the most used methods to assess the functional muscle strength as well as the balance and the functional mobility of elderly people (Bohannon, 2006; Buatois et al., 2006), thus allowing identification of those individuals with impaired balance (Whitney et al., 2005). In a study carried out by Aslan et al., 2008, who applied the sit-to-stand test to young and older adults, the results showed that elderly individuals spent more time to perform the tasks compared to the young ones. Zech et al., 2011 also shown that the sit-to-stand power test can be efficient to distingue between nonfrail elderly and prefrail. In elderly women with 60 years and older, both higher muscle mass and lower body fat were positively associated with physical function, evaluated by walking speed and sit-to-stand test (Visser et al., 2000).

The five-repetition sit-to-stand test has been used to evaluate muscle strength and balance. However, the action of sitting and standing involves a complex integration of muscular strength and muscle power, range of movement, postural control and coordination pattern (Karikanta et al., 2005). Some studies shown that the muscle contraction speed is very important to perform the sit-to-stand test, as fast as possible, and the weak power probably contributes to loss of mobility and it can better predict falls than muscle strength analysis (Skelton et al., 2002; Petrella et al., 2005). Also, the sit-to-stand test is adequate to evaluate muscle power in elderly population (Zech et al., 2011).

In a study conducted by Netz et al., 2004, they observed that the sit-to-stand test when performed 10 times consecutively, as fast as possible, is not able to predict knee extensor strength, but it can be used to predict general endurance. Also, they suggest that the peak aerobic capacity is related to the performance of the test. However, the sit-to-stand test 10 times is a longer activity that increase the chance of both muscle fatigue and change of coordination pattern, and possibly requires more of the cardiorespiratory system. Therefore, future studies must be performed to compare the methodologies (five versus ten times sit-to-stand test).

Nevertheless, it is not clear if the reduction of both muscle function and postural stability is more pronounced in women with osteoporosis. The impairment on the ability to perform functional tasks (for example: standing up and sitting down) can make these individuals more susceptible to falls and subsequent fractures. The rate of falls among the elderly is high and the fractures occurrence and severe lesions lead to a partial or total decrease in their daily activity performance and autonomy, with a negative impact in their quality of life (Shimada et al., 2003).

Therefore, in order to evaluate the association between bone mineral density and dynamic balance of elderly women, the sit-to-stand test was used, since it seems to be a clinical test capable of evaluating muscle function and balance. The variables obtained were maximum antero-posterior trunk movement during the sit-to-stand tasks and time spent during the test.

The data shown that women with osteoporosis had greater movement of the trunk during standing up and sitting down tasks compared to other groups of women. The results suggest that the decrease in BMD can occur in association with a reduction in the functional capacity of muscular system, due to the fact that muscular and skeletal systems act as a unique unit. A previous study shown that osteoporotic women are more likely to fall than the non-osteoporotic ones within the same age group, due to the fact that osteoporotic women have greater weakness of the quadriceps and impaired postural control (Lynn et al, 1997). The quadriceps muscle is important for performing the sitting down/standing up movement, which might explain why the group of osteoporotic had a greater anterior-posterior movement of the trunk as a way of compensating for such a muscle weakness (Bohannon, 2006; Lord et al.; 2002).

Moreover, the women with T score between -1 and - 2.5 SD (osteopenia) had greater movement of the trunk in relation to the group of women presenting normal bone mineral density (T score greater than – 1 SD) during stand up from the chair. This finding is very relevant, since it shown that women with osteopenia already perform compensation during the dynamic activity. The fact of women with osteoporosis have greater movement of the trunk during standing up and sitting down suggests a quadriceps function deficit during concentric and eccentric contractions, while the fact that women with osteopenia have greater movement of the trunk only during standing up suggests some quadriceps muscle function deficit only during concentric contraction.

Based on the literature, the aging process affect negatively all contraction muscle types (concentric, eccentric and isometric strengths) (Lindle et al., 1997; Porter et al., 1995), however, the concentric knee extension strength decreases more than eccentric strength. Therefore, it seems that women with osteoporosis have a more pronounced decline of muscle contraction strength, with impairment during concentric and eccentric movements.

The compensatory movement by the trunk dislocation is worrying, since the high degrees of trunk flexion movement displaces the centre of gravity anteriorly, and associated to the decrease of postural stability and muscle function, the control of body mass centre is prejudiced, resulting in difficulty to maintain the state of balance during the sit-to-stand task, which increases the risk of fall among the osteoporotic women.

There was no difference between groups when compared the time spent during the sit-to-stand movements ($P > 0.05$), probably due to the higher trunk flexion performed by groups with osteoporosis and osteopenia, which compensate the lower limb muscles deficit and, consequently, allowed them to achieve the same time during the test. However, in some studies in which the sit-to-stand test was applied to elderly individuals, the results regarding the time spent for performing the tasks are close to those obtained in the present study (Whitney et al., 2005; Aslan et al., 2008; Schaubert & Bohannon, 2005), which suggests that the decrease of the movement velocity is associated to many factors of aging process and not to the bone mineral density (BMD) directly.

The spent time to perform the five-chair sit-to-stand test in women aged 65 years or older with osteopenia (Chyu et al., 2010; Alp et al., 2007) was similar to the present study. In another study conducted with osteoporotic women (Alp et al., 2007), the sit-to-stand test was performed 10 times as quickly as possible, and the values obtained was approximately twice the time spent by women in our study (in our study they performed the sit-to-stand movements five times consecutively as quickly as possible).

Lindsey et al, 2005 did not observe a correlation between sit-to-stand test performance and BMD of any skeletal site in older women, which is in agreement with our findings, since we did not find differences in time spent during the sit-to-stand test between groups. Also, in a systematic literature review conducted by Hyehyung et al., 2011, no correlation was observed between lower femoral/lumbar BMD and slower sit-to-stand test in age-adjusted models.

The obtained results point out an interesting discussion on which parameters should be considered in assessments of dynamic balance and functional activity, since the compensatory movements can mask the deficits of analyzed variables. In our study, the antero-posterior trunk dislocation probably was the compensatory movement due to the lower limbs muscle weakness. The lack of difference in the spent time during the sit-to-stand test is probably a consequence of the compensatory movement. This aspect has already been raised by Netz et al., 2004, since they discussed that the STS ten times not include the trunk control analysis.

Hence, the evaluation of spent time to perform the STS test by itself would not be enough to identify impairment in the dynamic activity in women with greater bone losses and wrong conclusions about the muscle strength and balance characteristics could have been done.

In relation to the muscular system, the aging process interferes negatively in muscle characteristics (Zech et al., 2011; Clark BC & Taylor, 2011; Buffa et al., 2011), and following the muscle-bone unit theory, women with greater bone losses also present greater muscle function alterations. Therefore, the compensatory movement (increase of the trunk dislocation) observed during the sit-to-stand test can also be associated to a decrease of muscle function, which includes strength, power and muscle mass, without disconsidering the other components involved during the test. However, future research is needed to verify the muscle function in women with different levels of bone mineral density.

Our hypothesis was in part confirmed, since women with different classifications of BMD presented different anterior-posterior displacements of the trunk, but not presented differences of time spent to perform the sit-to-stand test.

Besides, the results show that women with osteopenia also have increase in the trunk dislocation, and based on a study by Siris et al, 2001 which shown that osteopenic women had 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.

A recent study evaluated the physical performance of women aged 45 to 64 years, through evaluations that included sit-to-stand test (Khazzani et al., 2009). The results showed that low physical performance was associated with low BMD of spine and hip. In addition, some studies shown that regular training to strengthen the muscles of the lower limbs, especially the quadriceps, are effective for increasing muscle power, static and dynamic balance, thus improving performance activities of daily living, which includes the act of sitting down and up (Khazzani et al., 2009; Teixeira et al., 2010). Also, high-impact loading exercise has shown to be efficient to increase bone mass and geometry in postmenopausal women (Hamilton et al., 2010; Iwamoto et al., 2010). Another study that conducted a 11-month exercise program, which included strength, aerobic capacity, balance, joint mobility on ground and in the water on postmenopausal women shown an improvement of physical function capacity, associated to a reduction of physiological bone loss (Tolomio et al., 2010).

Those studies ratify the importance of exercise programs in order to improve muscular and bone systems and to improve balance and functional capacity. The conservation of muscle function seems to be essential to keep a sufficient mechanical stimulus on bone, and consequently, to minimize the bone decline over time.

These data emphasize the need to encourage women with different levels of bone loss to adhere to exercise programs in order to improve their balance, functionality and bone characteristics, thus reducing the risk of falls and fractures consequently.

7. Conclusions

The results suggest that osteoporotic women exhibit a greater trunk movement compared to women with less bone loss, which is associated to impairment of both postural control and muscle function. However, women with T score ranging from -1 to - 2.5 SD (low bone mineral density) had a greater impairment compared to the group of women with T score greater than -1 SD.

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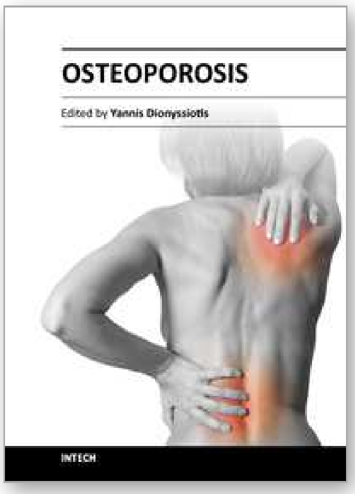

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Osteoporosis is a public health issue worldwide. During the last few years, progress has been made concerning the knowledge of the pathophysiological mechanism of the disease. Sophisticated technologies have added important information in bone mineral density measurements and, additionally, geometrical and mechanical properties of bone. New bone indices have been developed from biochemical and hormonal measurements in order to investigate bone metabolism. Although it is clear that drugs are an essential element of the therapy, beyond medication there are other interventions in the management of the disease. Prevention of osteoporosis starts in young ages and continues during aging in order to prevent fractures associated with impaired quality of life, physical decline, mortality, and high cost for the health system. A number of different specialties are holding the scientific knowledge in osteoporosis. For this reason, we have collected papers from scientific departments all over the world for this book. The book includes up-to-date information about basics of bones, epidemiological data, diagnosis and assessment of osteoporosis, secondary osteoporosis, pediatric issues, prevention and treatment strategies, and research papers from osteoporotic fields.