Anteroposterior displacement behavior of the center of pressure, without visual reference, in postmenopausal women with and without lumbar osteoporosis

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OBJECTIVE: The aims of this study were to evaluate the anteroposterior displacement behavior of the center of pressure without any visual reference and determine its relationship with knee muscle strength and reports of falls in postmenopausal women. Among those with osteoporosis, the specific objective was to evaluate the correlation of thoracic kyphosis and vitamin D with center of pressure displacement.

METHODS: This was a cross-sectional observational study without intervention. The assessments were performed on 126 postmenopausal women (aged 55-65 years) who were grouped according to their lumbar bone density into osteoporosis and control groups. Center of pressure was evaluated on a force platform (100 Hz frequency and 10 Hz filter), with the subjects standing on both feet with eyes closed for 60 seconds. Knee muscle strength was evaluated using an isokinetic dynamometer in concentric/concentric mode at a velocity of 60°/s. In the osteoporosis group, vitamin D was assayed, and the thoracic spine was radiographed.

RESULTS: In the control group, there was a correlation between the center of pressure and knee strength ($r = 0.37$; $p < 0.003$). Reports of falls were not associated with center of pressure displacement ($p = 0.056$). In the osteoporosis group, thoracic kyphosis and vitamin D levels were not correlated with the center of pressure.

CONCLUSION: Anteroposterior center of pressure displacement without visual influence was not associated with falls, thoracic kyphosis or vitamin D in the osteoporosis group. Only knee muscle strength was associated with center of pressure displacement in the control group.

KEYWORDS: Muscle Strength; Osteoporosis; Postmenopause; Postural Balance.

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INTRODUCTION

Postural control is the inherent capacity to maintain the center of mass within the base of support, which defines the stability limits. These limits are the edges of the operational areas through which the center of mass can be displaced without the need to move the base of support (1). The center of pressure (COP) is the point of application of the vertical resultant force (in this case, from the human body, when standing on both feet) acting on the base of support (2). According to Lynn et al. (3), changes to the body caused by osteoporosis displace the COP such that it nears the stability limits, thereby leading to loss of balance and falls. The parameter most used in evaluating postural balance, which is performed using a force platform, is the COP (2). COP sway is a risk factor for falls (4), and elderly people who fall have greater COP sway (5).

It is known that maintenance of postural control, consequent to achieving postural balance, depends on the quality of vision (6-7), which is responsible for 23% of balance maintenance (8).

Loss of muscle strength and power is a hallmark of the aging process (9) that is associated with poor functional abilities among older adults (10). Several tasks of daily living, including walking, stair climbing and rising from chairs, have been shown to be related to the ability to generate strength and power around the knee joint (11). In women, the decline of estrogen levels after menopause contributes to imbalance and loss of muscle strength (12). Compared to women without osteoporosis, postmenopausal women with

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osteoporosis are at greater risk of falling when they present diminished hand grip, trunk extension and lower-limb extension strength (13).

Maintenance of muscle strength and power as well as better postural balance among elderly individuals have been correlated with vitamin D supplementation (14). Furthermore, increased thoracic kyphosis is often related to osteoporosis (15) and age, thereby leading to anterior inclination of the trunk (7,16), which is a factor that may increase the risk of falls and fractures in this population (16,17).

With advancing age, the habit of going to the bathroom during the night increases. This is often performed without turning the lights on or without putting glasses on; thus, a large portion of the visual references that are essential for maintaining postural balance are lost. In these situations, the risk of falls is high, and among women with osteoporosis, such falls may have severe consequences. Thus, the present study was developed to assess the anteroposterior displacement behavior of the COP with eyes closed and its relationship with knee muscle strength and reports of falls during the past year among postmenopausal women with and without osteoporosis. The secondary objective of this study was to correlate the degree of thoracic kyphosis and 25-OH vitamin D assays with anteroposterior COP displacement among those with osteoporosis.

METHODS

Ethics

The study was performed at the Laboratory for the Study of Movement, Institute of Orthopedics and Traumatology, Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HC-FMUSP). The study was approved by the Ethics Committee of the University of São Paulo (number 320/09). After the study was explained to the patients, they provided signed consent forms.

Sample size

The sample size calculation was based on a pilot study that included 15 postmenopausal women and considered the variable of anteroposterior COP displacement with eyes closed. To compare two means, the conditions specified were a test power of 80%, a significance of 5%, a standard deviation of 0.18 and the possibility of detecting a difference of 0.09. To meet these conditions, at least 63 subjects were required in each group (control and osteoporosis).

Experimental design and subjects

This was a cross-sectional observational study, without intervention, in which 126 postmenopausal women aged 55 to 65 years were included. The patients originated from two disease groups and were treated at Hospital das Clínicas da Faculdade de Medicina da Universidades de São Paulo (Figure 1), and two new groups of 63 patients each were selected for the present study: a control group (CG), consisting of women with normal vertebral bone mineral density (BMD) (T-scores greater than −1 SD), and an osteoporosis group (OPG), consisting of women with osteoporotic BMD (T-score lower than −2.5 SD). These groups were defined in accordance with the World Health Organization criteria. BMD was measured using dual-energy X-ray absorptiometry. The subjects had a normal vestibular system and no proprioceptive, auditory or neurological conditions. Within the past six months, they had not been prescribed any antipsychotic medication, had no restrictions on vigorous physical activity, had not undergone any surgery and had not suffered any injury to their legs. Patients were excluded if they presented any blood pressure abnormalities or if they were unable to perform the test.

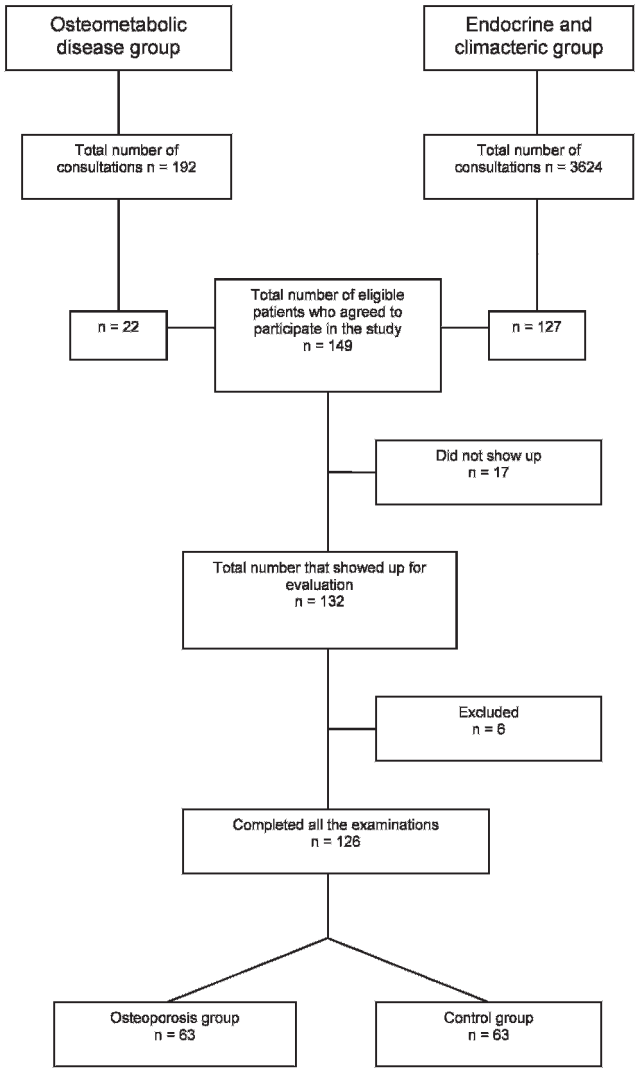

Figure 1 - Flow diagram for subject selection.

Measurements

Initially, a questionnaire seeking personal and anthropometric data and the international physical activity questionnaire (IPAQ, short version) were administered. The subjects were also asked about any falls that they had experienced during the preceding 12 months. Falls were defined as unintentional events in which the individual ended up at a lower level than the initial position (18). Following this, the subjects underwent static balance assessment (posturography) on a portable force platform (AccuSway Plus; AMTI®, MA, USA). For data acquisition, the force platform was connected to a signal-amplifying interface box (PJB-101) that was attached to a computer by an RS-232 cable. The data were gathered and stored using Balance Clinic® software configured for a frequency of

100 Hz with a fourth-order Butterworth filter and a cutoff frequency of 10 Hz. All the subjects underwent the test with standardized positioning in relation to the maximum width of the base of support and regarding their arm and head positions. Three 60-second measurements were performed with eyes closed. The arithmetic means from the three tests conducted under each condition were calculated, and the results were processed using Balance Clinic® software. The parameter used to measure the subjects' stability with eyes closed was the root mean square of the displacements from the center of pressure (COP) in the anteroposterior plane (YSD).

Evaluation of knee extension-flexion (concentric-concentric) isokinetics was performed in a Biodex Multi-Joint System 3 dynamometer (Biodex Medical™, Shirley, NY, USA). The tests were first performed on the dominant leg. After a standardized warm-up, the subjects were positioned on the equipment in accordance with the manufacturer's instructions (seated with arms hanging against the body, hands holding the lateral handles and strap stabilization for the trunk, hip and tested thigh). Gravitational correction was performed at with the knee flexed to 40°. Isokinetic testing at 60°/sec (concentric/concentric) was used for data collection. The subjects performed three submaximal repetitions prior to data collection. Five maximal repetitions were performed twice, and a 60-second rest period was used between tests for all subjects. Subsequently, the same procedure was performed for the non-dominant leg. Consistent verbal commands were given during the tests, and all tests were conducted by the same examiner. Peak torque adjusted for body weight (PTQ/BW) was the variable assessed. To analyze the data, only the values from the second set of five maximal repetitions were used due to the effects of motor learning on clinical isokinetic performance (19).

The OPG underwent 25-OH vitamin D blood tests to measure the level of vitamin D and radiography on the thoracic spine in lateral view to measure the degree of thoracic kyphosis according to the regional Cobb angle (from the fourth to the ninth thoracic vertebra, i.e., T4-T9) and the overall Cobb angle (from the second to the twelfth thoracic vertebra, i.e., T2-T12) (20).

Statistical Analysis

To investigate associations between the characterization variables of the groups, Student's t test was used for the quantitative variables, and the chi-square test or likelihood ratio test was used for the qualitative variables. The correlation between the variables of muscle strength and postural balance was evaluated using Spearman's correlation coefficient. From the correlated variables, a multiple linear regression model was then fitted with YSD as the response variable. The following explanatory variables were considered: group, fall, muscle strength and an interaction term between group and variable power to account for differences in the coefficient of the variable force between groups. In the OPG, the correlations between thoracic kyphosis and 25-OH vitamin D assays and the variables of muscle strength and postural balance were investigated using Spearman's correlation coefficient. Normal data distributions were verified by constructing graphs of normal probabilities. In the multiple linear regression analysis, the assumptions of normal distribution and equality of error variance were assessed using residual analysis. The software programs used in the data analysis were Minitab® (version 15) and SPSS® (version 18). In the hypothesis tests, the significance level was set at 0.05.

RESULTS

Table 1 shows the mean values and standard deviations of the baseline characteristics in the control (n = 63) and osteoporosis groups (n = 63). The hypothesis of equality between the control and osteoporosis groups was tested, and the results are provided.

In the OPG, the mean 25-OH vitamin D level was 26.7 ± 9.5, the regional degree of kyphosis was 33.4 ± 8, and the overall mean Cobb angle was 45.4 ± 10.1. Spearman's correlation was used to evaluate the correlation between muscle strength and postural balance variables. The coefficients were calculated according to group (CG and OPG). The coefficients (r) and the *p*-values determined from the significance tests are presented in Table 2.

Multiple linear regression models were fitted to examine the associations between the balance variable and group, falls and muscle strength using the anteroposterior COP displacement (YSD response) as the variable. The explanatory variables were group, falls, one muscle strength variable and one interaction term between the group and the strength variable, which allowed the coefficient of the strength variable to differ between groups. This variable was chosen based on the results presented in Table 2 (the variable chosen had to be correlated with the response). Residual analysis was used to evaluate assumptions of normal distribution and equality of variance.

YSD response variable:

- The difference between the YSD means in the two groups depended on PTQ/BW (there was an interaction between YSD and PTQ/BW) ($p = 0.015$). When comparing the YSD means in the two groups

Table 1 - Baseline characteristics of the groups.

	Osteoporosis Group	Control Group	
Age (years)	60.6 (±3.1)	60.0 (±3.0)	
Caucasian	79%	65%	
Bone densitometry			
Lumbar spine			
BMD (g/cm^2)	0.73 (±0.1)	1.04 (±0.1)	*
SD	- 3.01 (±0.5)	- 0.10 (±0.7)	*
Femoral neck			
BMD (g/cm^2)	0.70 (±0.2)	0.90 (±0.1)	*
SD	- 1.81 (±0.7)	- 0.05 (±1.2)	*
Total hip			
BMD (g/cm^2)	0.78 (±0.1)	0.98 (±0.1)	*
SD	- 1.63 (±0.8)	0.01 (±1.0)	*
Dominance (right)	97%	95%	
Body weight (kg)	59.8 (±10.5)	69.2 (±10.5)	*
Height (m)	1.52 (±0.1)	1.55 (±0.1)	*
BMI (kg/m^2)	25.8 (±4.2)	28.9 (±4.6)	*
Physical activity (IPAQ)			
Active	44%	44%	
Irregular activity	56%	56%	
Report of falls in the past year			
Yes	43%	30%	
No	57%	70%	

Bone mineral density (BMD); standard deviation (SD); body mass index (BMI); International Physical Activity Questionnaire (IPAQ).
*$p<0.001$.

Table 2 - Correlation between muscle strength and anteroposterior COP displacement variables.

Group	Variable		Dominant		Non-dominant	
			Extension	Flexion	Extension	Flexion
			PTQ/BW	PTQ/BW	PTQ/BW	PTQ/BW
CG	YSD	r	-0.16	**-0.37**	-0.11	-0.16
		p	0.225	**0.003**	0.394	0.208
OPG	YSD	r	-0.11	-0.04	-0.21	-0.06
		p	0.409	0.757	0.105	0.625

COP: center of pressure; PTQ/BW: peak torque/body weight; CG: control group; OPG: osteoporosis group; YSD: root mean square of the displacements of the center of pressure in the anteroposterior plane
Data representing Pearson's correlation coefficient (r) with $p<0.01$ are in bold.

at the midpoint of PTQ/BW, there was a significant difference between the means in the two groups ($p = 0.036$) such that the mean for the CG was higher than the mean for the OPG.

- Within the same fall category and the same PTQ/BW value, there was no significant difference in YSD between the two groups ($p = 0.056$).
- In the OPG, there was no association between YSD and PTQ/BW ($p = 0.984$); in the CG, there was an association between YSD and PTQ/BW ($p = 0.001$), and YSD decreased by 0.003 cm/s (standard error = 0.0008) with every one-unit increase in PTQ/BW.

Table 3 presents the correlations of the degree of thoracic kyphosis and 25-OH vitamin D assays with the balance variable in the OPG.

DISCUSSION

We were unable to find any previous studies evaluating anteroposterior COP displacement in relation to falls and isokinetic knee muscle strength in association with vitamin D assays and the degree of thoracic kyphosis among postmenopausal women.

The results from this study demonstrated that within this age group, the anteroposterior COP displacement was greater among women without osteoporosis. Isokinetic muscle strength was not associated with anteroposterior COP displacement. Thoracic kyphosis and 25-OH vitamin D

Table 3 - Correlation of thoracic kyphosis and 25-OH vitamin D with anteroposterior COP displacement.

		YSD
25-OH vitamin D	r	-0.01
	p	0.948
T2-T12	r	0.01
	p	0.951
T4-T9	r	0.07
	p	0.579

COP: center of pressure; T4-T9: regional Cobb angle from the fourth to the ninth thoracic vertebra; T2-T12: overall Cobb angle from the second to the twelfth thoracic vertebra; YSD: root mean square of the displacements of the center of pressure in the anteroposterior plane
Data represent Pearson's correlation coefficient (r).

at these levels did not correlate with anteroposterior COP displacement among the women with postmenopausal osteoporosis.

It is known that elderly women frequently present diminished lower-limb muscle strength, and this is believed to be a predisposing factor for falls (21). Posturography is considered to be the gold standard for assessing postural balance, and the variable of COP displacement presents the greatest amplitude along the anteroposterior plane (22). Lynn et al. (3) and Abreu et al. (23) reported that elderly women with osteoporosis had worse postural balance than women without osteoporosis, although Abreu et al. (24), Silva et al. (25) and Brech et al. (26) stated that osteoporosis did not worsen postural balance among elderly women. In the present study on postmenopausal women, there was no association between reports of falls and anteroposterior COP displacement in either group, although other studies found a relationship between reports of falls and side-to-side displacement (7). The fact that the present study evaluated women at the start of menopause may be one of the reasons why the reports of falls did not have a relationship with COP displacement. It is possible that the falls reported by these subjects were unrelated to loss of balance.

The anteroposterior COP displacement with eyes closed was greater in the control group; this finding differed from those of Abreu et al. (23) and Silva et al. (25), who reported that women with osteoporosis presented greater COP displacement in this plane and under this condition. We have previously reported that greater COP mediolateral displacement is related to the occurrence of falls in the preceding year in postmenopausal women (5). However, Abreu et al. (24) stated that one limit of their own study was the lack of a control for muscle strength, given that better muscle condition could increase COP sway (27). Thus, it is questionable whether greater COP displacement represents imbalance and a risk of falling or whether it might signify greater muscle control, with the capacity to maintain greater COP displacement within the same base of support by nearing the stability limits.

Vitamin D acts as a hormone by regulating calcium absorption in the intestine, and it is also extremely important for maintaining muscle strength (28), particularly quadriceps strength (29). According to Bischoff-Ferrari (30), vitamin D supplementation may decrease the risk of falling among elderly women with vitamin D deficiency by up to 49% (31). In the present study, there was no correlation between anteroposterior COP displacement and vitamin D levels, and we found no other studies that identified such correlations. We believe that in the present study, the vitamin D levels of the subjects were not low enough to influence the maintenance of postural balance.

Similar to the vitamin D levels, the degree of thoracic kyphosis was also not correlated with anteroposterior COP displacement. However, the subjects did not present very marked kyphosis, given the age group studied, which may have influenced the results. Thoracic kyphosis tends to increase with age (17), and this increase occurs more rapidly (within three years) for women with osteoporosis (32).

Study Limitations

The limitations of the present study include the age group studied (55-65 years), considering that such individuals may not present notable abnormalities in anteroposterior COP

displacement due to their relative youth. However, we chose to evaluate this population because we wanted to examine the behavior of these variables without the influence of musculoskeletal aging. We did not assess ''fear of falling'', which is an important variable given that individuals with greater fear of falling tend to maintain postures that are more rigid during balance evaluations. Falls among women with osteoporosis may be more closely related to dynamic balance, such as that exerted while walking and changing positions, and less related to static balance. Future studies should seek to assess the balance abilities of these women under more challenging conditions, such as eyes closed on unstable surfaces or eyes closed while performing verbal double tasking. In addition, future studies should seek to evaluate groups with different levels of vitamin D and greater angles of thoracic kyphosis to identify the real influence of these variables on postural balance.

Women with osteoporosis present a high rate of fractures related to falls, which may be very serious because of the clinical complications resulting from hospitalizations to treat the fractures. Large numbers of elderly women fall during the night when they are headed to the bathroom. It is known that preventive measures such as keeping a light on and the removal of loose rugs present on the way from the bed to the bathroom are important strategies for preventing falls. The present study has demonstrated that women do not present any predisposition to falls caused by changes in anteroposterior COP displacement at the start of the postmenopausal period, which represents a significant clinical contribution. In addition, the degree of thoracic kyphosis and the 25-OH vitamin D levels measured in the present study were not associated with and did not increase the risk of falls among postmenopausal women with osteoporosis.

Postmenopausal women, with or without lumbar osteoporosis, do not present abnormalities in anteroposterior COP displacement when they do not have a visible reference point. This result was independent of knee muscle strength or whether the women suffered falls during the preceding year. Among postmenopausal women with osteoporosis, the degree of kyphosis and the 25-OH vitamin D levels noted in these experiments did not influence anteroposterior COP displacement.

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■ AUTHOR CONTRIBUTIONS

Brech GC, Fonseca AM and Bagnoli VR performed the data collection, analysis and prepared the manuscript. Baracat EC and D'Andrea Greve JM supervised the study and revised the manuscript.

■ REFERENCES

1. Alexander NB. Postural control in older adults. J Am Geriatr Soc. 1994;42(1):93-108.
2. Duarte M, Freitas SM. Revision of posturography based on force plate for balance evaluation. Rev Bras Fisioter. 2010;14(3):183-92, http://dx.doi.org/10.1590/S1413-35552010000300003.
3. Lynn SG, Sinaki M, Westerlind KC. Balance characteristics of persons with osteoporosis. Arch Phys Med Rehabil. 1997;78(3):273-7, http://dx.doi.org/10.1016/S0003-9993(97)90033-2.
4. Barr R, Macdonald H, Stewart A, McGuigan F, Rogers A, Eastell R, et al. Association between vitamin D receptor gene polymorphisms, falls, balance and muscle power: results from two independent studies (APOSS and OPUS). Osteoporos Int. 2010;21(3):457-66, http://dx.doi.org/10.1007/s00198-009-1019-6.
5. Brech GC, Plapler PG, de Souza Meirelles E, Marcolino FM, Greve JM. Gait Posture. 2013;38(2):321-5.
6. Lord SR, Menz HB. Visual contributions to postural stability in older adults. Gerontology. 2000;46(6):306-10, http://dx.doi.org/10.1159/000022182.
7. Nardone A, Schieppati M. The role of instrumental assessment of balance in clinical decision making. Eur J Phys Rehabil Med. 2010;46(2):221-37.
8. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. J Gerontol. 1991;46(3):69-76, http://dx.doi.org/10.1093/geronj/46.3.M69.
9. Hartmann A, Knols R, Murer K, de Bruin ED. Reproducibility of an isokinetic strength-testing protocol of the knee and ankle in older adults. Gerontology. 2009;55(3):259-68, http://dx.doi.org/10.1159/000172832.
10. American College of Sports Medicine. Position Stand on Exercise and physical activity for older adults. Med Sci Sports Exerc. 2009;41(7):1510-30.
11. Skelton DA, Greig CA, Davies JM, Young A. Strength, power and related functional ability of healthy people aged 65–89 years. Age Ageing. 1994;23(5):371-7, http://dx.doi.org/10.1093/ageing/23.5.371.
12. Naessen T, Lindmark B, Larsen HC. Hormone therapy and postural balance in elderly women. Menopause. 2007;14(6):1020-4.
13. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. Osteoporos Int. 2005;16(8):1004-10, http://dx.doi.org/10.1007/s00198-004-1791-2.
14. Dukas L, Schacht E, Runge M. Independent from muscle power and balance performance, a creatinine clearance below 65 ml/min is a significant and independent risk factor for falls and fall-related fractures in elderly men and women diagnosed with osteoporosis. Osteoporos Int. 2010;21(7):1237-45, http://dx.doi.org/10.1007/s00198-009-1064-1.
15. Kado DM, Huang MH, Nguyen CB, Barrett-Connor E, Greendale GA. Hyperkyphotic posture and risk of injurious falls in older persons: the Rancho Bernardo Study. J Gerontol A Biol Sci Med Sci. 2007;62(6):652-7, http://dx.doi.org/10.1093/gerona/62.6.652.
16. Katzman WB, Vittinghoff E, Kado DM. Age-related hyperkyphosis, independent of spinal osteoporosis, is associated with impaired mobility in older community-dwelling women. Osteoporos Int. 2011;22(1):85-90, http://dx.doi.org/10.1007/s00198-010-1265-7.
17. Kado DM, Lui LY, Ensrud KE, Fink HA, Karlamangla AS, Cummings SR. Study of Osteoporotic Fractures. Hyperkyphosis predicts mortality independent of vertebral osteoporosis in older women. Ann Intern Med. 2009;150(10):681-7, http://dx.doi.org/10.7326/0003-4819-150-10-200905190-00005.
18. Stoddart H, Sharp D, Harvey I, Whitley E. Falls and the use of health services in community-living elderly people. Br J Gen Pract. 2002;52(484):923-5.
19. Brech GC, Ciolac EG, Secchi LL, Alonso AC, Greve JMA. The effects of motor learning on clinical isokinetic performance of postmenopausal women. Maturitas. 2011;70(4):379-82, http://dx.doi.org/10.1016/j.maturitas.2011.09.004.
20. Sinaki M, Lynn SG. Reducing the risk of falls through proprioceptive dynamic posture training in osteoporotic women with kyphotic posturing: a randomized pilot study. Am J Phys Med Rehabil. 2002;81(4):241-6.
21. Pijnappels M, van der Burg PJ, Reeves ND, van Dieën JH. Identification of elderly fallers by muscle strength measures. Eur J Appl Physiol. 2008;102(5):585-92.
22. Rougier PR. Relative contribution of the pressure variatinos under the feet and body weight distribution over both legs in the control of upright stance. J Biomech. 2007;40(11):2477-82, http://dx.doi.org/10.1016/j.jbiomech.2006.11.003.
23. Abreu DC, Trevisan DC, Costa GC, Vasconcelos FM, Gomes MM, Carneiro AA. The association between osteoporosis and static balance in elderly women. Osteoporos Int. 2010;21(9):1487-91, http://dx.doi.org/10.1007/s00198-009-1117-5.
24. Abreu DC, Trevisan DC, Reis JG, da Costa GD, Gomes MM, Matos MS. Body balance evaluation in osteoporotic elderly women. Arch Osteoporos. 2009;4(1-2):25-9, http://dx.doi.org/10.1007/s11657-009-0023-y.
25. Silva RB, Costa-Paiva L, Oshima MM, Morais SS, Pinto-Neto AM. Frequency of falls and association with stabilometric parameters of balance in postmenopausal women with and without osteoporosis. Rev Bras Ginecol Obstet. 2009;31(10):496-502, http://dx.doi.org/10.1590/S0100-72032009001000005.
26. Brech GC, Alonso AC, Luna NM, Greve JM. Correlation of postural balance and knee muscle strength in the sit-to-stand test among women with and without postmenopausal osteoporosis. Osteoporos Int. 2013;24(7):2007-13, http://dx.doi.org/10.1007/s00198-013-2285-x.
27. Laughton CA, Slavin M, Katdare K, Nolan L, Bean JF, Kerrigan DC, et al. Aging, muscle activity, and balance control: physiologic changes

associated with balance impairment. Gait Posture. 2003;18(2):101-8, http://dx.doi.org/10.1016/S0966-6362(02)00200-X.
28. Shinchuk LM, Holick MF. Vitamin d and rehabilitation: improving functional outcomes. Nutr Clin Pract. 2007;22(3):297-304, http://dx.doi.org/10.1177/0115426507022003297.
29. Bischoff-Ferrari HA, Dietrich T, Orav EJ, Hu FB, Zhang Y, Karlson EW, et al. Higher 25-hydroxyvitamin D concentrations are associated with better lower-extremity function in both active and inactive persons aged > or =60 y. Am J Clin Nutr. 2004;80(3):752-8.
30. Bischoff HA, Stähelin HB, Dick W, Akos R, Knecht M, Salis C, et al. Effects of vitamin D and calcium supplementation on falls: a randomized controlled trial. J Bone Miner Res. 2003;18(2):343-51, http://dx.doi.org/10.1359/jbmr.2003.18.2.343.
31. Bischoff-Ferrari HA, Conzelmann M, Stähelin HB, Dick W, Carpenter MG, Adkin AL, et al. Is fall prevention by vitamin D mediated by a change in postural or dynamic balance? Osteoporos Int. 2006;17(5):656-63, http://dx.doi.org/10.1007/s00198-005-0030-9.
32. Roux C, Fechtenbaum J, Kolta S, Said-Nahal R, Briot K, Benhamou CL. Prospective assessment of thoracic kyphosis in postmenopausal women with osteoporosis. J Bone Miner Res. 2010;25(2):362-8., http://dx.doi.org/10.1359/jbmr.090727.