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Evaluation of the association between osteoporosis and postural balance in postmenopausal women

Guilherme Carlos Brech [a,b,*], Pérola Grinberg Plapler [c], Eduardo de Souza Meirelles [c], Flora Maria D'Andrea Marcolino [c], Júlia Maria D'Andrea Greve [a]

[a] Department of Orthopedics and Traumatology, Faculdade de Medicina da Universidade de São Paulo (FMUSP), São Paulo, Brazil
[b] Laboratory of Kinesiology, Instituto de Ortopedia e Traumatologia, Faculdade de Medicina da Universidade de São Paulo (IOT/FMUSP), São Paulo, Brazil
[c] IOT/FMUSP, São Paulo, Brazil

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ABSTRACT

The incidence of osteoporosis has been increasing, as have fractures resulting from falls. Postural balance was evaluated in postmenopausal women with and without lumbar osteoporosis. One hundred and twenty-six postmenopausal women aged 55–65 years were evaluated and separated into two groups according to the bone mineral density values of their lumbar spine: the osteoporosis group and the control group, paired by age ($P = 0.219$) and physical activity ($P = 0.611$). There was no difference between the groups ($P = 0.139$) regarding falls reported in the previous 12 months. Functional mobility was evaluated through the Timed Up and Go Test. Postural balance was evaluated using a portable force platform in standard standing position, with eyes open and closed, for 60 s. Muscle strength was evaluated through an isokinetic dynamometer. This study shows that there is no difference in knee muscle strength and functional mobility ($P = 0.121$), postural balance with eyes open [mediolateral displacement ($P = 0.286$) and mean velocity of the center of pressure (COP) ($P = 0.173$)] and with eyes closed [mediolateral displacement ($P = 0.163$), and the mean velocity of displacement of the COP ($P = 0.09$)] in both groups. Subjects reporting falls had greater mediolateral displacement ($P = 0.028$) in both groups. Postmenopausal women aged between 55 and 65 years do not present changes in postural balance irrespective of lumbar osteoporosis. Greater COP mediolateral displacement is related to the occurrence of falls in postmenopausal women in the previous year.

1. Introduction

Osteoporosis is a disease characterized by reductions in bone mineral density (BMD), deterioration of bone tissue, increased fragility, and risk of fractures. According to the World Health Organization (WHO), osteoporosis is defined as BMD loss exceeding −2.5 standard deviations (SD) (T-score) in relation to young adults [1]. It is one of the biggest public health problems, mainly because of the aging of the population. In Brazil, the national health system is experiencing increasing expenditures on treatments for fractures among elderly individuals, which resulted in 20,778,000 hospital admissions in 2006 [3].

Postural control is the inherent capacity to maintain the center of mass within the support base that defines the stability limits [4]. Elderly women with osteoporosis have greater postural imbalance and a greater predisposition to falls [2,6–8]. Women with osteoporosis have been described to have greater velocity [8] and more anteroposterior and mediolateral displacement of the center of pressure (COP) [2,6,7] than women of the same age without osteoporosis. Cangussu et al. [9] showed that BMD has no association with postural balance or risk of falls, but age does. Furthermore, it is known that elderly women with osteoporosis tend to use more hip strategy to maintain postural balance [10], but there are no reports of whether women with osteoporosis at the beginning of menopause present worse postural balance that could be related to risk of falls.

In women, the decline of estrogen after menopause contributes to imbalance and loss of muscle strength [11]. Muscle strength diminishes with aging, particularly that of the knee extensor

* Corresponding author at: Laboratório de Estudos do Movimento, Rua Dr. Ovídio Pires de Campos, 333 2° andar, São Paulo, SP 04503-010, Brazil.
Tel.: +55 11 9811 7869/2661 7812; fax: +55 11 2661 6908.
E-mail addresses: guibrech@gmail.com, guilhermebrech@yahoo.com.br (G.C. Brech), perolagp@yahoo.com (P.G. Plapler), emei@terra.com.br (E. de Souza Meirelles), floramarcolino@uol.com.br (F.M.D. Marcolino), jgreve@usp.br (J.M.D. Greve).

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muscles, thereby favoring postural imbalance and falls [12]. Di Monaco et al. [13] found an association between appendicular lean and fat mass in women after hip fracture. In this context, an evaluation of muscular performance may have important implications for prescribing interventions to counteract the age-related decline in muscle strength and its consequences related to worse postural balance and risk of falls.

Falls are the biggest cause of fractures among women with osteoporosis [2], and approximately one-third of women older than 60 years fall at least once a year [14]. Detecting the factors that affect postural balance is fundamental for prevention programs. Most of the studies on osteoporosis and postural balance assessed elderly women aged 65 years or more. However, it is unclear whether osteoporosis affects postural balance in women at the beginning of menopause. Thus, the present study was developed in order to evaluate postural balance among postmenopausal women with or without lumbar osteoporosis.

2. Methods

2.1. Study location and ethical issues

The study was performed at the Motion Study Laboratory of the Institute of Orthopedics and Traumatology, Hospital das Clínicas, University of São Paulo School of Medicine with approval granted by the Ethics Committee of the University of São Paulo (number 320/09).

2.2. Sample size

The sample size calculation was based on a pilot study with 15 postmenopausal women and the variable mean velocity calculated from the total displacement of the COP in all directions was considered. To determine the sample size to compare the two means, the power of the test was set at 80% with a 5% level of significance, a standard deviation of 0.18 cm, and the possibility of detecting a difference of 0.09 cm. To meet these conditions, at least 63 subjects were needed in each group.

2.3. Subjects

This was a cross-sectional observational study without interventions including 126 postmenopausal women aged 55–65 years. Sixty-three subjects were included in each group: a control group (C) consisting of women with normal lumbar spine BMD (T-scores higher than −1 SD) and an osteoporosis group (OP) consisting of women with osteoporotic BMD (T-score lower than −2.5 SD), in accordance with the WHO criteria. BMD was measured using dual-energy X-ray absorptiometry (DXA).

The inclusion criteria for this study were: (1) absence of vestibular, proprioceptive, auditory, or neurological impairment, and/or of any mental disturbances or disorders; (2) no use of medications that might compromise postural balance; (3) absence of lesions, surgery, or disease that might have caused lower-limb joint limitations over the previous six months; (4) absence of lower-limb dysmetria; and (5) presence of clinically normal gait, without claudication. The exclusion criteria were the presence of pain or inability to complete any of the tests, or elevated blood pressure (over 120× 80 mmHg) before strength evaluation.

2.4. Measurements

The following data were initially collected during the interviews: age, age of menopause, race, and lower limb dominance. Weight, height, and body mass index (BMI) and DXA values were also collected. The International Physical Activity Questionnaire (short version) was used to characterize the subjects' physical activity level. Participants were asked whether they had fallen during the previous 12 months (answering "yes" or "no"). A fall was characterized as an unexpected unintentional position change that leads the individual to a lower level in relation to the initial position [15].

Participants then underwent the Timed Up and Go Test (TUGT) to measure functional mobility (time in seconds). The postural balance assessment (posturography) was performed 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 linked to a computer by means of an RS-232 cable. The data were gathered and stored using Balance Clinic® software, configured to a frequency of 100 Hz with a fourth-order Butterworth filter and a cutoff frequency of 10 Hz. All subjects underwent the test with standardized positioning in relation to the maximum width of the support base (smaller than hip width), with arms along the body and head looking straight at a target. The base of support was drawn on a paper on a fixed position on the force platform, corresponding to the anatomical points of distal hallux phalanx, fifth metatarsal head, and lateral and medial malleolus for each foot. Three measurements were made with the eyes open (EO) and three with the eyes closed (EC) for 60 s each. The arithmetic mean of the results was calculated from the three tests conducted under each condition and was processed using Balance Clinic® software. The parameters used to measure the subject's stability with eyes open and closed were the root mean square of the displacement from the COP in the mediolateral axis (XSD) and the mean velocity calculated from the total displacement of the COP in all directions (VAvg).

Isokinetic dynamometry was performed using the Biodex® Multi-joint System 3 (Biodex Medical™, Shirley, NY, USA). The isokinetic dynamometer was calibrated 30 min before starting the tests. After a standardized warm-up, the subjects were positioned for concentric evaluation of extension and flexion movements of the knee joint. They remained seated with the hips at 90° of flexion and secured to the chair by belts. The test was started with the dominant limb. The limb was evaluated by positioning the lateral condyle of the femur in alignment with the mechanical axis of the dynamometer. All subjects performed four submaximal repetitions to became familiar with the equipment, followed by a 60-s rest interval, then two series of five maximal repetitions of knee extension and flexion starting with the dominant limb, with a 60-s intervals between the series. The values from the second series were used for data analysis regarding the effects of motor learning on clinical isokinetic performance [16]. Constant standardized verbal encouragement was given during the tests in order to promote maximum effort during contractions. The isokinetic variable used was maximum peak torque corrected for body weight (PTQ/BW).

2.5. Statistical analysis

To investigate associations among the characteristic variables of the two groups, the Student's t test was used for the parametric quantitative variable. The chi-square test was used for parametric categorical data and the maximum likelihood ratio for non-parametric qualitative variables. Assumptions of normality and homogeneity of variance were evaluated by constructing normal probability plots. The Mann–Whitney test was used to compare the muscle strength (PTQ/BW in the dominant and non-dominant sides in flexion and extension) of the two groups. The Student's t test was used when comparing the XSD and VAvg means of the two groups by condition. The assumption of homogeneity of variance was verified by Levene's test. The correlations between the muscle strength and postural balance variables were evaluated by means of Spearman's correlation coefficient. Based on the correlated variables, multiple linear regression models were then fitted. The analysis was performed with the aid of Minitab (version 15) and SPSS (version 18). The significance level for testing the hypotheses was set at 0.05.

3. Results

Table 1 shows the mean values, standard deviation, and results for testing the hypothesis of equality between the control ($n = 63$) and osteoporosis groups ($n = 63$) regarding baseline character-

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%
Menopause		
Age when menopause started (years)	46.8 (±5.0)	47.0 (±5.9)

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