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Does Osteoarthritis Further Compromise the Postural Stability of Women with Osteoporosis?

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SUMMARY

Background. It is known that women with osteoporosis display only slight deficits in postural control. However, a condition that often co-exists with OP is osteoarthritis (OA), which has been shown to significantly compromise balance. To establish reasonable inclusion criteria for balance assessment of women with OP and investigate if specific treatment regimens are necessary for those subjects, it is important to evaluate the differences in postural control and postural strategies between the two groups.

Material and methods. We compared postural sway in quiet standing measured by the parameters of the center-of-pressure (COP) signals, recorded on a force plate, of 30 women with osteoporosis and 27 women with coexisting mild osteoarthritis.

Results. Our results indicated that the latter subjects had higher COP sway in the sagittal compared with the frontal plane, while the former subjects had similar sway in both planes. Subjects with both conditions relied more on vision to preserve postural stability compared with subjects with osteoporosis alone, and they also appeared to compensate further with a higher frequency of their body oscillations.

Conclusions. 1. Even mild symptoms of osteoarthritis may affect balance and misrepresent the observed postural behavior in stabilographic studies. 2. The indications for the treatment regimens of individuals with osteoporosis may differ depending on the presence of co-existent osteoarthritis.

Key words: postural sway, balance deficit, stiffness, confounding variable

BACKGROUND

Osteoporosis (OP) is a debilitating systemic condition characterized by compromised bone strength, which predisposes an individual to high risk of fracture [1]. Bone mineral density, body sway, and muscle strength have been reported to be independent and powerful synergistic predictors of fracture incidence [2]. Programs for improving muscle strength have been used for a long time with good results [3]. Exercise intervention studies, however, report little change in bone mineral density, although mechanical loading may improve bone strength by reshaping its structure without increasing actual mineral density [4]. Thus, the fundamental task for the therapist is to prescribe remedial treatment for deteriorated balance in people with OP.

We have shown recently [5] that although physical activity is reported to improve the quality of the life of people with OP, it does not necessarily ameliorate postural instability. Hue et al. [6] reported no improvement in standing balance in older people after an individualized three-month program designed to improve their posture, balance and mobility. A similar lack of effect of individualized interventions including exercise and strategies for maximizing vision and sensation were reported by Lord et al [3]. These investigators concluded that the lack of an effect on falls may reflect insufficient targeting of the intervention to an at-risk group. Although it seems apparent that balance exercises prescribed for people with OP should directly address the factors responsible for their balance deficits and the mechanisms involved, these attempts have met with limited success.

As a basis for the present study, we propose to explain the findings of previous studies in two ways. The first is related to methodology, specifically in terms of applied measures of postural stability. Traditional measures of the variability of the center-of-pressure (COP) and means of evaluating their interrelationship, which were examined in previous studies, may have been insufficient to disclose actual changes in the dependent variables pre- and post-intervention. In fact, our recent results have shown, using correlation analysis, that women with OP who participated in a structured exercise program for 6 months displayed a more optimistic model of ageing than their sedentary counterparts [7]. Very likely, the application of viscoelastic [8] or chaotic measures of the COP in similar studies could have resulted in more conclusive and subject-specific data.

The second explanation is also related to methodology. Recruitment of older people has been criticized for using both too conservative and too liberal inclusion criteria. Conservatism might eliminate subjects with self-reported good health from participation even though their medical history indicates otherwise [9]. As proposed by Stelmach et al. [10] the use of highly selected older adults could overestimate the postural control of 'less healthy' elderly people. Those 'less healthy' are probably a better representation of the elderly population as a whole, but the assessment of postural stability in subjects who, beside the pathology of main interest, have co-existent conditions that affect balance, may significantly distort the results. Thus, any attempt to design effective therapy based on such results may be futile.

A condition which often co-exists with OP because of people's advancing age is osteoarthritis (OA), which, like OP, has been shown to affect balance. The causes of poorer balance in people with OA, however, are different from those with OP although some common factors may co-exist, e.g., being sedentary, being post-menopausal, or general ageing.

The purpose of this study therefore was to compare the postural stability of women with OP with women who additionally have OA. We hypothesized that the latter subjects would exhibit more greatly impaired balance and different postural strategies than the former ones. Accordingly, we hypothesized that the presence of OA should be included in the exclusion criteria when recruiting people with OP for stability studies.

MATERIAL AND METHODS

Our subjects were selected from a larger cohort of 395 post-menopausal women with OP who had been recruited into another study. Inclusion criteria of the cohort were a bone mineral density (BMD) T-score at least one standard deviation below the young normal sex-matched score, independence of living and self-reported good health. Subjects were excluded if they had apparent musculoskeletal or neurological impairment. Upon arrival at the laboratory, they were asked to provide information pertaining to their history of falls, subjective unsteadiness, physical exercise, and pain incidents that lasted longer than one week (all no/yes answers) during the last 6 months prior to the investigation. They were also asked about their current physical and mental status including pain, fatigue and arousal.

In the cohort, we identified 27 women with mild OA proven by their radiographic data indicating coxarthrosis or gonarthrosis, and they were assigned to the OPOA group (aged 65.4 ± 10.3 years, with height 155.7 ± 4.8 cm, body mass 65.7 ± 10.3 kg, and BMD T-score -2.4 ± 1.1. Of the remaining subjects in the cohort, thirty women were randomly selected and assigned to the OP group (aged 66.3 ± 5.9 years, with height 158.4 ± 5.8 cm, body mass 64.2 ± 10.9 kg, and BMD T-score -2.7 ± 0.5).

Postural stability was assessed in two successive 20s quiet stance periods on a custom-made strain-gauge force plate, first with eyes open and then with eyes closed. During each stance the COP signal was recorded in the anterior-posterior (AP) and medial-lateral (ML) planes for subsequent analysis. The dependent variables included the traditional measures of the COP, namely standard deviation, range, and mean velocity. Additionally, we computed the viscoelastic (VE) parameters of stance [8] represented here by the frequency of postural corrections and postural stiffness. The latter parameters were computed from the difference between the COP and the center-of-mass (COM) using procedures described in [8].

Statistical computations were performed using Statistica 7.0®. To compare the performance of our subjects with OP with the results of those with OPOA, descriptive statistics (mean ± S.D.) based on the repeated ANOVA (visual condition x plane) were calculated for the variables of interest. Relationships between dichotomous and continuous variables were computed using the point biserial correlation. Alpha was set at $p = 0.05$.

RESULTS

A face-to-face interview revealed that none of the subjects on the day of investigation was fatigued, unduly anxious or aroused, or in any pain. The history of imbalance and falls reported was 73% and 43% for the OP subjects vs. 67% and 26%, for the OPOA subjects, respectively. The incidence of pain was more prevalent in the OPOA subjects (78%) than in those with OP alone (47%). Approximately three-quarters of participants in each group described themselves as being sedentary (74-75%). We found no relationship between the history of incidences of imbalance and/or falls reported by subjects and parameters of the COP, except several low but significant correlations in the OPOA group. Specifically, measures of the COP dispersion correlated with history of imbalance ($r = 0.40$ to 0.49, $p<0.05$) and physical activity ($r = -0.45$ to -0.40, $p<0.05$).

The comparison of the COP between eyes open versus eyes closed stances in both groups of subjects is presented in Table 1a for the AP and in Table 1b for the ML measures of sway. Eyes closure increased the values of all parameters in the AP and ML plane in subjects with OPOA, while in their counterparts with OP, the COP variability in the ML plane remained unchanged. Additionally, the dependence on visual cues for balance appeared to have been stronger in the OPOA group and was associated with an increased mean velocity and postural stiffness ($p=0.0002$ and $p=0.01$) compared with the OP group ($p=0.04$ and $p=0.58$) in the AP plane (Table 1a).

Beside direct comparisons, we found significant GROUP x PLANE interactions of the range ($p= 0.0003$), standard deviation ($p=0.005$), and mean

Tab. 1. Comparison of the postural stability variables of women with osteoporosis with and without osteoarthritis. The data are descriptive statistics of stabilographic variables (repeated ANOVA) (mean ± S. D) derived from center-of-pressure measurements (EO- eyes open, EC- eyes closed).

a)						
	Women with Osteoporosis Alone (n=30)			Women with Osteoporosis and Osteoarthritis (n=27)		
	Anteroposterior Plane					
	EO	EC	p	EO	EC	p
Standard deviation [mm]	3.9 ± 1.2	4.9 ± 1.9	0.05	4.6 ± 2.1	6.0 ± 2.9	0.005
Range [mm]	18.3 ± 5.6	24.5 ± 8.2	0.003	23.0 ± 9.4	31.8 ± 17.0	0.002
Mean velocity [mm/s]	8.8 ± 5.3	11.8 ± 4.1	0.04	10.8 ± 5.3	17.5 ± 10.4	0.0002
Frequency [Hz]	0.61 ± 0.18	0.64 ± 0.15	-	0.57 ± 0.17	0.70 ± 0.15	0.005
Stiffness [Nm/rad]	1043 ± 572	1214 ± 468	-	1000 ± 477	1454 ± 748	0.01
b)						
	Mediolateral Plane					
Standard deviation [mm]	4.3 ± 1.7	4.6 ± 2.0	-	3.5 ± 1.2	4.7 ± 2.6	0.01
Range [mm]	21.4 ± 8.3	21.9 ± 9.4	-	16.9 ± 6.4	23.9 ± 12.1	0.01
Mean velocity [mm/s]	8.6 ± 3.7	11.5 ± 6.6	0.01	8.1 ± 3.2	12.4 ± 7.2	0.0002
Frequency [Hz]	0.59 ± 0.13	0.69 ± 0.20	0.0004	0.60 ± 0.09	0.70 ± 0.12	0.0005
Stiffness [Nm/rad]	992 ± 385	1365 ± 757	0.0004	1041 ± 373	1418 ± 558	0.0006

velocity (p=0.002) values that revealed different coordination in the two groups regarding the mechanisms responsible for postural control in each plane. Also, there was a GROUP x VISION interaction in the mean velocity values (p=0.04). Subsequent post-hoc analysis indicated higher values of all AP parameters of the COP sway with eyes closed in the OPOA than in OP subjects (Table 1): standard deviation (p< 0.05), range (p<0.02), and mean velocity (p<0.0002). The latter results give an insight into a higher reliance on vision in the OPOA subjects compared to the OP subjects in the AP plane.

DISCUSSION

The main purpose of this study was to identify hypothesized differences between individuals with OP with and without OA with respect to gross postural sway and postural strategies. Specifically, we investigated the traditional parameters of COP dispersion and the characteristics of the corrective signal equal to the COP - COM, which represents active torque generated by the CNS in maintaining balance [8].

One important difference between the OP and OPOA subjects is the relative contribution of the AP and ML variability to the dispersion of the COP. While the OP subjects swayed slightly less in the AP than ML plane, which differentiates them from healthy subjects and concurs with the findings of other investigators [5], the OPOA individuals produced significantly higher sway in the AP plane as demonstrated by all measures of the COP. Thus, the latter subjects, apart from having higher absolute COP variability in both planes than healthy elderly, had a very similar AP/ML variability ratio compared with healthy subjects. Put another way, the OPOA individuals have preserved an increased (compared to healthy people) ML sway reported by some investigators [11,12] which was interpreted as a specific compensatory strategy used by the OP subjects to shorten their reaction time in balance recovery [5], being likely an important measure to avoid a fall. However, they differed from their OP counterparts in this study in that they had higher values of sway in the AP plane. Increased sway has been associated with altered somatosensory input in the elderly [9]. In the OPOA subjects it may be indeed the reason for higher variability of the AP COP as subjects with OA were reported to have impaired proprioception, particularly in extended knee joint positions [13], and reduced quadriceps motoneuron excitability [14]. Those deficits are mainly responsible for the postural control in the AP plane, which is supported in our data by the increase in sway of the OPOA individuals in that plane, only as indicated by significant GROUP x PLANE interactions.

By directly comparing the traditional sway parameters in the AP plane in the eyes closed stances, the differences between the two groups become even more apparent. Specifically, the results of the OPOA group are 22% (p<0.05) larger in standard deviation, 30% (p<0.02) larger in range, and 48% (p<0.0002) larger in mean velocity. These results, with the mean velocity in particular, indicate that the OPOA subjects rely more on visual cues to maintain balance compared with subjects with OP alone. Stronger reliance on vision is usually evidence of a decline in other sources of afferent information, with somatosensory input being a sole candidate in this study.

It remains to justify why the deterioration of somatosensory information may influence the velocity of sway? Velocity has been recently reported as the afferent which is the most important source of information providing the central nervous system (CNS) with the measure of error and dynamic stability in the postural control system [15]. It is possible that the articular damage characteristic of people with OA, which has been reported to decrease somatosensory input [13], may require specific compensation manifested by the increased velocity of sway, which serves to monitor the departure from a set value. Put another way, an intact position detection system can easily dispense without a high rate of monitoring, while the presence of errors or noise in that system may require a more tight operation mode in terms of more frequent output control, thus increasing the velocity.

Strong support for the latter notion comes from comparing the values of postural stiffness and frequency in the AP plane (Table 1a). Closing the eyes had no effect on stiffness and frequency in the OP subjects, indicating that in spite of the increase in sway they felt in full control of their balance, presumably having intact vestibular and somatosensory systems. On the other hand, eye closure increased stiffness (p<0.01) and frequency (p<0.005) in the OPOA subjects, indicating that the lack of visual input had been identified by the CNS as a challenge that required special measures to effectively preven stable posture.

In contrast to the differential involvement of the CNS in both groups in the AP plane to compensate for the lack of visual input in the trial with eyes closed, changes in the frequency of corrective torque and postural stiffness revealed similar strategies in all subjects in the ML plane (Table 1b). After eye closure the subjects in both groups stiffened their posture, probably by activating the hip abductors and adductors, and produced a higher frequency of postural oscillations. While comparing that effort to the commonly reported lack of vision-related changes in posture in the ML plane in healthy older people [8] may seem a superfluous means employed by our subjects, several investigators have argued that postural unsteadiness and related problems appear primarily associated with aberration in the ML plane [5, 16].

As can be seen from the data in Table 1b, the increase in stiffness and frequency helped the OP subjects maintain their sway variability at a level similar to that recorded with eyes open. Increased mean velocity was a natural consequence of higher frequency. However, the OPOA subjects, who applied the same stiff strategy of stance, failed to control their sway amplitude and all parameters of their COP variability significantly increased. We initially associated OA with postural instability in the AP plane. However, this condition may also seriously affect postural control in individuals with OPOA in the ML plane. Although the execution of motor commands in the latter plane is mainly achieved by the hip abductors and adductors, the information regarding the actual values of sway may be transmitted by the knee joints or even generated by the knee loading/unloading mechanism. The confirmed articular damage in subjects with OA may disturb the somatosensory input and send noisy afferent information to the CNS, thus interfering with postural control in those subjects.

CONCLUSIONS

1. Deterioration of balance is more pronounced in women with osteoporosis combined with osteoarthritis than in those with osteoporosis alone.
2. People with osteoporosis coupled with even mild osteoarthritis may need to be excluded from investigations of people with osteoporosis.
3. Patients with and without osteoarthritis form distinct groups of people with osteoporosis. Different individualized approaches to treatment are indicated for each.
4. A primary explanation for a balance deficit in people with combined osteoporosis and osteoarthritis may be impaired proprioception in the knee and hip joints.

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