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Effects of Regular Walking on Postural Stability in the Elderly

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Key Words

Postural control · Force platform · Pressure center, postural sway · Postural limits · Maximal voluntary isometric contraction · Two-point discrimination

Abstract

Background: Both age and lack of physical activity may be responsible for poor health and poor balance control. Conversely, physical activity may modulate postural control in elderly people. ***Objective:*** An observational study was performed in older adults to explore whether walking on a regular basis might prove to be beneficial not only to the cardiovascular system but also to maintaining a good balance. ***Methods:*** Twenty-two healthy older subjects walking on a regular basis (DW group) and 121 healthy control older subjects who did not walk regularly (NW group) were studied. The subjects included in the study were free from major gait and postural disorders. An instrumented force platform was used to measure the time-varying displacements of the center of pressure under eight static conditions and postural limit tests. An isometric test was performed to evaluate lower limb muscle strength, and a static two-point discrimination test evaluated the innervation density of the slowly adapting receptors of the sole of the first toe. ***Results:*** The DW group had a significantly better ($p < 0.05$) postural stability under static conditions than the NW group. There were no significant differences in postural limit tests and in two-point discrimination between the groups. The DW group had significantly higher values of ankle plantar flexor and knee extensor strengths, while there were no significant differences in ankle dorsiflexors and knee flexors. None of the DW group reported experiencing a fall during the previous 6 months compared with 16% in the NW group who reported at least two falls during the last half year. ***Conclusions:*** Walking on a regular basis in old age may have the potential to modulate stability. It was found that healthy older subjects, who walked on a regular basis since their retirement, have better postural control, especially in their static balance, than those who do not. The laboratory results were accompanied by the important finding that although older subjects who walk on a regular basis walked much more than nonwalkers, they did not suffer from falls.

Introduction

Age and lack of physical activity may both be responsible for a poor balance control. Conversely, physical activity may modulate the postural control in elderly people.

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Aging is accompanied by a decrease in walking ability, functional performance, muscle strength, and postural steadiness [1–5]; it is, therefore, often speculated that these decreases are related. This study attempted to determine whether walking on a regular basis would affect postural steadiness as well as postural stability limits and whether they are related to lower limb muscle strength in healthy older adults.

Researchers have noted the psychological and physiological benefits of exercise in the elderly [6, 7]. Well-documented studies have shown improvements in muscle strength [8], muscle mass [9], bone mass [10], cardiovascular state, endurance [11], and hypertension [12] in older adults who exercised. Moreover, physical activity has a beneficial influence on psychological function and decreases the incidence of depression [10]. These multiple actions explain that physical activity, including walking on a regular basis, improves the quality of life in older adults. In the elderly subject, preservation of balance is fundamental to maintaining functional independence. Aging and lack of physical activity, associated with diverse disease states, dangerously alter the balance function, particularly the anticipated adjustments which allow an adaptation of posture to movement.

Less is known about the effects of walking on a regular basis on the postural stability in aging individuals. The question asked by the investigators was: Does walking on a regular basis maintain stability and prevent falls that lead to the most common accidental injuries among the elderly?

Subjects and Methods

One hundred and forty-three healthy volunteers aged 65 years and over participated in the case-control study (table 1). This is a retrospective, analytical, observational study based on laboratory and clinical data on 22 walkers who, since they retired (14.1 ± 2.3 years ago), walked on a regular basis at least three times a week 2 km each time which was accomplished within 30–40 min (DW group) and 121 control subjects who did not walk regularly (NW group). The subjects were free from neurological and/or psychiatric disorders and did not show signs of any serious cognitive dysfunction.

Balance measurements were made using a firmly secured force platform (AMTI) consisting of one aluminum plate placed on four force transducers (hysteresis and nonlinearity $<0.1\%$), recording the vertical ground reaction forces. Signals were processed by six DC amplifiers (nonlinearity $<0.1\%$) and first-order low-pass filters (cut-off frequency 100 Hz) and then stored in a microprocessor after AD conversion at a sampling rate of 200 Hz. Calculations were made by digital movement of force. The cross-talk values were compensated for by a calibration test prior to data collection. The virtual center of the ground reaction forces, in a two-dimensional transverse plane, was determined for each sample with a maximum error of ± 1 mm in both directions. The coordinates of the center of pressure (COP) were passed through a digital low-pass 5-Hz filter, and the smoothed fluctuations of the COP were further processed by a first-order differentiation of the displacements.

Table 1. Characteristics of the DW and NW groups (mean ± SEM)

	DW group (n = 22)	NW group (n = 121)
Age, years	75.0 ± 1.3	77.9 ± 1.54
Male/female ratio	6/16 (37.5%)	31/90 (34.4%)
Height, cm	161.2 ± 2.3	159.3 ± 0.7
Weight, kg	69.3 ± 3.3	68.7 ± 1.1
Years of DW	14.1 ± 2.3	–
Foot length, cm	23.9 ± 0.4	23.1 ± 0.2
TPD, mm	12.3 ± 0.7	13.5 ± 0.4
Unexplained falls the past half year	0/22	19/121
Knee extension MVIC, Nm	97.5 ± 12.0*	74.6 ± 6.9
Knee flexion MVIC, Nm	39.7 ± 3.9	33.4 ± 4.2
Plantar flexion MVIC, Nm	60.8 ± 7.1*	47.4 ± 2.3
Dorsiflexion MVIC, Nm	24.7 ± 2.5	20.5 ± 0.9

* $p < 0.05$.

Strength measurements were made on the dominant leg using a Biodex (Shirley, N.Y., USA) isokinetic dynamometer (system 2). All subjects performed maximal voluntary isometric contraction (MVIC) in ankle dorsiflexion/plantar flexion and knee flexion/extension while sitting on a standard dynamometer with the back slightly reclined at approximately 75° and the thigh well supported by the seat. Stabilization in the seated position was achieved by pelvic and thoracic strapping. The dominant leg was secured to chair and dynamometer lever arm. Lower limb segments were firmly strapped; the moving limb segments were aligned parallel to the arm of the dynamometer. The axis of rotation of ankle and knee joints and lever arm coincided. The subjects were tested for ankle plantar flexion and dorsiflexion and knee flexion extension strength by exerting MVIC for 5 s × 3 repetitions.

For the two-point discrimination (TPD) test, the skin of the sole of the 1st toe was touched firmly with a discriminator that has two prongs. The subjects' task is to determine whether one or two prongs are touching them. If the prongs are far apart, it is easy to detect the two points of touch. However, as the prongs are brought closer together, it becomes difficult to determine whether the touch is by one or two prongs. The smaller the distance between the two prongs that the subject can detect, the more sensitive the sense of touch. The static TPD test evaluates the innervation density of the slowly adapting fibers/receptors at the sole of the 1st toe. The discriminator prongs are held perpendicular to the long axis of the plantar surface of the 1st toe and placed on the skin only with sufficient pressure for a subject to determine that he/she is being stimulated, not to cause pain. The subject's two-point value is that at which he/she gives two correct answers out of three.

Study Protocol

After the subjects removed their shoes and socks, we measured their weight, height, and foot length. They completed a questionnaire to establish their medical background, perception of their health, activity level, and unexplained falls during the prior half year.

Balance was registered for a period of 20 s in each position. The subjects stood erect on the force platform with 17 cm between the heel centers and with each foot turned out at a 14° angle from the sagittal midline [13]. The subjects were instructed to stand still and as symmetrically as possible, with their hands folded on their back.

Eight static conditions were measured, four single-task and four dual-task conditions. A dual-task procedure was developed to estimate the level of automaticity of a quiet upright-standing task [14]. The modified Stroop test [14] was used because the test demands a considerable amount of focused attention, few instructions, and shows relatively small long-term learning effects. It does not address the memory, which is often impaired in the elderly, and it requires only verbal responses. Simultaneous performance of modified Stroop test and balance task provides information that was not obtainable from simple upright standing. This information could be interpreted in terms of automatic balance behavior. It was, therefore, predicted that the interference effect would be reduced in the elderly who walk regularly.

Eight different conditions were evaluated. Four conditions were applied with wide base of support (feet apart): (1) a single task, standing upright with eyes open; (2) a dual task, standing upright while performing a cognitive task (modified Stroop test) with eyes open; (3) a single task, standing upright with eyes closed, and (4) a dual task, standing upright while performing a cognitive task (arithmetic test) with eyes closed. – Four further conditions were applied with a narrow base of support (feet together): (5) a single task standing upright with eyes open; (6) a dual task, standing upright while performing a cognitive task (modified Stroop test) with eyes open; (7) a single task, standing upright with eyes closed, and (8) a dual task, standing upright while performing a cognitive task (arithmetic test) with eyes closed.

The subjects were instructed to start the modified Stroop test as soon as possible. The modified Stroop test was projected onto a screen (approximately 200 cm wide, 120 cm high) at eye level. The test consisted of the presentation of 25 colored words (five lines of five words, word size approximately 5 cm wide × 10 cm high), representing color names that were always different from the printed colors. For example, the word yellow was presented in red. The subjects were instructed to name the colors as quickly as possible, until the end of the procedure (measured in 20th of a second). At the same time, they had to suppress the strong tendency to read the words. Before performing the balance test, this task was practiced once in a sitting position. In the arithmetic test, the subjects were instructed to subtract, as quickly as possible, from an arbitrary starting number between 50 and 100, the number that was given to them verbally at the beginning of the stability test. They had to continue the subtractions until the end of the test.

Stability limits were measured during maximum voluntary exertions of the center of pressure while leaning forward and backward and left and right in upright standing to the outer limits of their stability margins. Each extreme position was held for 1–2 s. The ability to control body lean may be more reflective of the functional activity such as reaching or transfers than standing body sway.

Statistics

A t test was employed to determine if statistically significant differences existed in the mean MVIC of ankle plantar/dorsiflexion, knee flexion/extension, and mean TPD measurements between the groups. The biomechanical laboratory parameters of balance performance were expressed as length of the COP path, value of the COP velocities, and elliptical area of 95% of COP points. Sways in anteroposterior and mediolateral directions were measured for the stability limits test. The results are presented as mean values ± SEM, taking a two-tailed probability of 5% as the level of significance.

Results

Single-Task Performance

There were significantly less COP path length and COP velocity (23.5 and 27.3%, respectively) in the DW group than in the NW group in the upright standing position with eyes open under the wide-base condition. Also under the narrow-base condition with eyes open, there were significantly less COP path length and COP velocity (11.1 and 10%, respectively) in the DW group than in the NW group (table 2).

Standing upright with eyes closed under the wide-base condition, there were significantly less COP path length and COP velocity (18.5 and 21.5%, respectively) in the DW group as compared with the NW group. Also with the eyes closed under the narrow-base condition, there were 19% less COP path length and 17.9% less COP velocity in the DW group than in the NW group. There was no significant difference in elliptical area between the groups in all single-task performances (table 2).

Dual-Task Performance

Standing upright while performing a cognitive task (modified Stroop test) under the wide-base condition showed 24.4% less COP path length and 21.5% less COP velocity in the DW group than in the NW group. With dual-task under the narrow-base condition, there were 17.4% less COP path length and 18.1% less COP velocity in the DW group than in the NW group. Performing a cognitive task (arithmetic test) with the eyes closed, under the wide-base condition, the COP path length was 26.7% less and the COP velocity 25% less in the DW group than in the NW group. Similar results were found for the narrow-base condition: the COP path length was 16.4% less and the COP velocity 16.2% less in the DW group than in the NW group. No significant differences were found in elliptical area (table 2).

Table 2. Force platform parameters of postural stability: DW and NW groups (mean ± SEM)

	Single task		Dual task	
	DW group	NW group	DW group	NW group
Wide base				
Eyes open				
Elliptical area, cm^2	1.5 ± 0.2	1.7 ± 0.1	3.99 ± 1.3	3.8 ± 0.5
COP path, cm	16.6 ± 1.0*	21.7 ± 0.9	21.7 ± 1.2*	28.7 ± 1.3
COP velocity, cm/s	0.8 ± 0.1*	1.1 ± 0.1	1.1 ± 0.1*	1.4 ± 0.1
Eyes closed				
Elliptical area, cm^2	2.04 ± 0.6	1.9 ± 0.2	2.1 ± 0.4	2.6 ± 0.3
COP path, cm	22.6 ± 2.7*	27.7 ± 1.3	24.2 ± 1.5*	32.99 ± 2.0
COP velocity, cm/s	1.1 ± 0.1*	1.4 ± 0.1	1.2 ± 0.1*	1.6 ± 0.1
Narrow base				
Eyes open				
Elliptical area, cm^2	5.7 ± 0.9	5.8 ± 0.3	4.8 ± 0.6	4.8 ± 0.2
COP path, cm	36.2 ± 2.2*	40.7 ± 1.1	34.2 ± 1.7*	41.4 ± 1.4
COP velocity, cm/s	1.8 ± 0.1*	2.0 ± 0.1	1.7 ± 0.1*	2.1 ± 0.1
Eyes closed				
Elliptical area, cm^2	8.2 ± 1.6	9.5 ± 0.5	8.9 ± 2.4	7.0 ± 0.5
COP path, cm	45.3 ± 4.6*	55.9 ± 2.2	51.1 ± 3.98*	61.1 ± 2.8
COP velocity, cm/s	2.3 ± 0.2*	2.8 ± 0.1	2.6 ± 0.2*	3.1 ± 0.1
Postural limits				
Mediolateral sway, cm	14.4 ± 1.4	12.6 ± 0.6		
Anteroposterior sway, cm	10.2 ± 0.7	9.7 ± 0.4		

* $p < 0.05$.

Postural Limits

No significant differences were found between groups while performing maximum voluntary exertions: 14.4 cm sway in mediolateral and 10.2 cm in anteroposterior directions in the DW group compared with 12.6 cm sway in mediolateral and 9.7 cm in anteroposterior directions in the NW group (table 2).

Muscle Strength Measurements

All measurements of strength were consistently higher in the DW group; the differences were statistically significant for ankle plantar flexors and knee extensors (table 1).

Self-Reporting of Falling

There was a significant difference between the two groups in self-reported falling. While none of the DW group reported falling, 16% of NW subjects reported that they had fallen at least twice during the last 6 months.

Two-Point Discrimination Test

The TPD test at the sole of the great toe showed no significant differences: 12.3 mm for the DW group compared with 13.5 mm for the NW group (table 1).

Discussion

Contrary to the popular belief that balance control degenerates as part of the aging process, this study suggests that older adults who have been walking on a regular basis since retirement can reduce the degeneration of postural stability and decrease unexplained fall events.

It has been found [Melzer et al., unpubl. data] that a 10–15% loss of muscle strength per decade occurs between the 5th and 8th decade, especially in postural muscles of the lower limb (quadriceps and plantar flexors) and less in the nonpostural muscle (tibialis anterior). Our findings suggest that these age-related changes decrease in older subjects who walk on a regular basis.

In this paper, we have shown that COP path length and COP velocity were significantly lower in the DW group across all COP-based measurements; however, no differences were found in the elliptical area in all conditions. These findings suggest that nonwalkers are increasing their effort in order to keep the COP within the 'safe area' of their base of support under both feet. The effect of walking on postural stability in the elderly has been little studied. Messier et al. [15] showed that 18-month aerobic walking programs significantly improved postural sway in older osteoarthritic adults relative to a control group. Judge et al. [16] found that a vigorous program of lower-extremity strengthening, walking, and postural control exercises in healthy older women improved the mean displacement of the COP in single stance by 17%. Rooks et al. [17] found that self-paced walking three times a week for 10 months significantly improved tandem and single-legged stance times with eyes open in older subjects; improvement in stair climbing speed and reduced tandem walking time were also noted.

Another important finding of the present study is that elderly walkers are better able to cope with cognitive tasks and upright-standing tasks. The findings suggest that their balance performance is more automatic (more skilled). Walkers showed significantly less interference effects than the controls on postural steadiness (postural sway) by the concurrent attention-demanding task; this might explain the fewer falls reported by walkers.

The influence of an attention-demanding task on postural control has been demonstrated in previous studies. During the modified Stroop task, Melzer et al. [2] found that elderly subjects stiffen up by cocontracting postural muscles. Furthermore, Brown et al. [18] showed that the ability to recover balance following a perturbation requires more attentional resources in healthy elderly than in young subjects, suggesting that with increasing age the performance of a motor task requires increased attention. Shumway-Cook and Woollacott [19] found that the ability to handle secondary tasks appears to further deteriorate in older adults with a history of recent falls. Also Brauer et al. [20] found that the ability to recover balance using a feet-in-place response was more attentionally demanding in the balance-impaired than in the healthy elderly persons. This suggests that the dual-task performance may contribute to postural instability and falls in balance-impaired elderly individuals. Lajoie et al. [21] found that elderly persons adopted a slower speed and shorter stride length when walking. These adaptations have been interpreted as producing a more secure gait. Even so, they responded to the probe cognitive task with greater delays than young adults did. Together, the results suggest that normal aging requires that a greater proportion of attention resources be allocated to the balance demands of postural tasks. Lassau-Wray and Parker [22] provided further support for the hypothesis that delays in the central processing of information during reaction tasks may occur with aging. Delays in neuromuscular response were significantly more frequent in older women, as the complexity of the walking reaction task increased. Hawkins et al. [23] found that following the 10-week exercise program, older exercisers showed substantially more improvement in alternation speed and time-sharing efficiency than older controls.

To conclude, this study suggests that regular walking after retirement is recommended not only for improvement/maintenance of muscle strength, bone mass, cardiovascular state, endurance, nutritional balance, and hypertension, but also for the maintenance of postural stability and balance control. Moreover, walking on a regular basis improves the quality of life in older adults and breaks down the cycle of disablement by interrupting or retarding the progression of disability.

Observational studies such as this provide weaker empirical evidence than do experimental studies because of the potential for large confounding biases to be present when there is an unknown association between a factor and an outcome. The symmetry of unknown confounders cannot be maintained. It remains to be determined whether the enhanced postural stability of elderly walkers is due to physical activity or to the well-being of the people who choose to walk on a regular basis. The greatest value of these types of studies is that they provide preliminary evidence that can be used as a basis for hypotheses in stronger experimental studies, such as randomized controlled trials.

Continued research is needed to identify age-related changes in postural control systems in old subjects who are less active. Much remains to be learned about the effects of walking on postural steadiness in old persons who do not walk regularly and about the risk of falling in these subjects.

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