CHANGES IN BALANCE PERFORMANCE IN PHYSICALLY ACTIVE ELDERLY PEOPLE AGED 73–80

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In our hospital in 1989 a series of 30 healthy elderly people participated in a study to evaluate the effect of physical training on improving balance. Thereafter, the majority of the people in this group continued with some kind of balance training. Seven years later we followed up 17 of the people who had participated in the original study. We wanted to evaluate the balance performance of these physically active elderly people (mean age 80.5 years) and compare it with their balance performance 7 years previously. Balance was found to be significantly impaired compared with 1989 in four out of six static balance tests. The time required to walk 30 m had increased significantly. The subjective ratings of vertigo and balance problems had not changed significantly, neither had the number of correct steps when walking forwards on one line and backwards between two lines. In dynamic posturography, the test with sway-referenced visual cues showed improved postural control, but no change in sway was seen in the other five sensory conditions. When sudden backward translations of the platform occurred, increased latencies of force response were seen.

Key words: aging, balance, exercise therapy.

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INTRODUCTION

In order to maintain postural control, humans continuously use information from somatosensory, visual and vestibular sources, resulting in efferent signals that activate appropriate postural muscles.

Tests measuring the time a certain position can be maintained (1, 2), quantifying body sway (3, 4) and measuring the latencies of balance responses (4) have shown impaired postural control with increased age. This can be a result of age-related changes in the balance system, age-related diseases and inactivity (5–7). In normal aging, walking speed decreases both at self-selected (8, 9) and maximal (10) speed. A significant association between increased postural sway and decreased walking speed has also been found (9, 11).

The numbers of falls, fractures and other fall-related injuries increase with higher age (12). In many studies, about 30–35% of subjects over the age of 65 years reported a fall during the year prior to questioning (9, 13, 14). Falls and fall-related injuries often mean suffering, immobility and a fear of falling again, as well as large healthcare costs. Impaired balance (15, 16) and osteoporosis (17) have been named as factors associated with falls and fractures in the elderly. Several gait parameters have been found to be impaired in elderly people with a history of falls compared with non-fallers (9, 18, 19). Iverson et al. (6) studied balance performance and activity levels in non-institutionalized men aged 60–90. Subjects who rated themselves as very active were able to stand for a significantly longer time in the sharpened Romberg eyes-closed position than those who considered themselves to be less active.

Although balance function decreases with increasing age, some studies have shown improved balance in the elderly after short-term physical training. In a study by Ledin et al. (20) an exercise group of 15 healthy elderly subjects aged 70–75 years was compared with a control group. The exercise group attended physical training with balance exercises twice a week for 9 weeks and dynamic posturography and clinical balance tests were performed before and after. The exercise group showed significant improvements in the following tests: standing on one leg with eyes closed; standing on one leg while turning the head; walking 30 m; and test conditions SO 4–6 in dynamic posturography.

This paper presents a follow-up study after 7 years of 17 of the 30 elderly subjects who participated in the study described by Ledin et al. (20). The purpose was to evaluate the change in balance performance in active healthy elderly people over the 7-year period.

PATIENTS AND METHODS

Subjects

Of the 30 subjects who participated in the original study 7 years prior to the present one, seven had subsequently died. Six of these had belonged

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Table I. *The groups the subjects belonged to in the original study and whether they participated in the follow-up 7 years later*

Group in former study	Deceased	Participated in follow-up: No	Yes	Sum
Exercise	1	3	11	15
Control	6	3	6	15
Sum	7	6	17	30

Exercise = belonged to former exercise group; control = belonged to former control group.

to the control group in the previous study. Of the remaining 23 subjects, 17 (6 men and 11 women) gave their informed consent to participate in the follow-up study. The mean age was 80.5 years (range 78–83). Of the six subjects who did not want to participate, four declined stating that they were unhealthy and two gave no reason (Table I).

Methods

The training. After the first study 7 years earlier, the subjects were offered a weekly 1-hour group exercise session 30 times a year. The physiotherapists who had designed the training programme in the former study led the group at the start. After 1 year, a gymnastic association for seniors took over the training and conducted it in accordance with the programme designed by the physiotherapists. The programme consisted of conditioning exercises, walking with different combinations of arm and leg movements, sudden turns and changes in position, visual fixation during head movements, balance exercises in standing and walking, coordination exercises, ball games, jumping on a trampoline and relaxation. The programme was carried out with an emphasis on balance training and to the accompaniment of music. The subjects did not specifically practice the balance tasks used in the assessment. Attendance was generally high, although exact information is not available.

Questionnaire. The questionnaire covered the following variables: vision, hearing, smoking and drinking habits, medicines, subjective change of physical activity level, falls, fractures and other fall injuries, hospital stays and use of walking aids. The subjects completed the questionnaire together with the investigator. The subjects also rated their degree of vertigo or dizziness using a 100-mm closed visual analogue scale with the endpoints *no symptoms* (0 mm) and *worst possible symptoms* (100 mm). The questionnaire was a modified version of the one used by Ledin et al. (20).

Static balance tests. The subjects' ability to stand without shoes in four different positions of the feet and with their eyes open or closed was tested. The tasks were timed with a stopwatch until the subjects moved their feet from the given position, opened their eyes on the eyes-closed tests, or reached the maximum time of 30 seconds. The positions of the feet were standing with feet together (Romberg's position); standing with one foot in front of the other (sharpened Romberg's position); and standing on one foot, both left and right. Every position was tested both with eyes open and with eyes closed. In the eyes-closed condition, posture was assumed prior to eye closure and, if the subjects opened their eyes, the time-keeping was stopped. Each test was performed three times and the best result was noted.

When the subjects stood on one foot they were instructed to lift the other foot to a level about halfway up the calf of the supporting leg without touching the supporting leg and to hold their arms vertically by the sides of their body. Compensatory movements of arms or the lifted leg were accepted without stopping the time-keeping. The time-keeping stopped if the supporting foot was moved from its initial position or if the lifted foot touched the floor. The test was performed on both the right and left legs; the best leg counted. These tests were performed in the manner described by Ledin et al. (20).

Walking tests. The subjects were asked to walk 30 m as fast as possible with their shoes on, making a turn of 180° after 15 m. The time was measured. They also walked without wearing shoes in two different tests: heel-to-toe 15 steps forward on one line and toe-to-heel 15 steps backward between two lines 20 cm apart. The number of correct steps was counted and the best result of three trials was used for analysis. These tests have been used in other studies (10, 20, 21).

Dynamic posturography. Subjects underwent a sensory organization test (SOT) and a movement coordination test (MCT) using a computerized dynamic posturography platform (Equitest, Neurocom Int. Inc., Clackamas, OR, USA) (22, 23). Neurocom has reported high intratrial reliability for both the SOT and the MCT and Ford-Smith et al. (24) have found the 1-week test–retest reliability of the SOT 1–2 and 4–6 to be fair-to-good and that of the SOT 3 to be poor.

The SOT assessed the three sensory components of balance under two different support conditions and three different visual conditions. The support surface was either fixed or sway-referenced (swayed with the subject) and the visual surround was either fixed or sway-referenced or the subject's eyes were closed. The contribution of each sense to the maintenance of balance could be measured when the other senses were absent or provided with conflicting information. In condition 1 (fixed support surface, eyes open) all sensory systems were present. In condition 2 (fixed support surface, eyes closed) visual cues were absent. In condition 3 (fixed support surface, sway-referenced vision) the visual cues were inaccurate. In condition 4 (sway-referenced support surface, eyes open) the somatosensory information provided was inaccurate. In condition 5 (sway-referenced support surface, eyes closed) the subject was forced to rely mainly on the vestibular system. In condition 6 (sway-referenced support surface, sway-referenced vision) both visual and somatosensory cues were inaccurate. The subjects' body sway was monitored by pressure-sensing strain gauges in the platform and postural stability was measured during a 20-second trial. A score of 100 represented no sway and a score of 0 represented maximum sway or a fall. The composite score was a weighted mean value of all conditions.

During the MCT the force response of each foot to sudden movements of the platform was measured. Medium and large backward and forward translation perturbations of the platform were performed and the latency (milliseconds) from translation onset to onset of force generation was measured. The average value from both feet was used for analysis.

Statistics. Descriptive statistics were used to show the characteristics of the subjects. The Wilcoxon signed-ranks sum test was used to analyse changes over 7 years by comparing the participants' results from the present study with those of the same 17 subjects from the original study. A significance level of $p < 0.05$ was used.

RESULTS

Description of subjects

Seven subjects had taken part in organized balance training for > 5 years since the first test occasion and eight for < 5 years. Three subjects had attended other forms of organized physical training and five performed balance exercises at home (Table II). All 17 subjects were still living at home. Seven years earlier (1989) 16 of the 17 subjects had been satisfied with their vision with or without glasses; at follow-up only 10 were satisfied with their vision. In 1989, 16 had said their hearing was good; at follow-up only 12 considered themselves to have good hearing. In 1989, one of the 17 subjects smoked; at follow-up all were non-smokers. At follow-up, the frequency of alcohol intake was found to be unchanged: 12 subjects consumed alcohol less than once a week and 5 once a week or more often. Thirteen subjects regularly used prescription medicines at the follow-up. The group as a whole used a mean of 0.6 ± 0.9 prescription medicines daily at the first evaluation and 2.3 ± 2.0 at the seven-year follow-up. The increase was significant ($p < 0.05$).

Seven years previously, three subjects reported a fall during the year prior to questioning. In the present study, the same three subjects and another two reported a fall the previous year. No-one reported multiple falls in the previous year. Three subjects

Table II. *Participation in the original study and training in the years until the follow-up*

Subject number	Group in former study	Organized balance training (years)	Other organized physical training (years)	Balance training at home
1	Exercise	7	0	No
2	Exercise	7	0	No
3	Exercise	7	0	No
4	Exercise	7	0	No
5	Exercise	6	1	No
6	Exercise	3	1	Yes
7	Exercise	1	0	Yes
8	Exercise	1	0	No
9	Exercise	0.5	0	Yes
10	Exercise	0.5	0	Yes
11	Exercise	0.5	0	No
12	Control	7	0	No
13	Control	6.5	0	No
14	Control	3	1	Yes
15	Control	1.5	0	No
16	Control	0	0	No
17	Control	0	0	No

had had one fracture each during the 7-year study period. There were six other fall injuries (five subjects) during the same time. The group as a whole had had 12 stays (8 subjects) in hospital, two because of falling. None of the subjects had used walking aids 7 years previously. In the present study, all subjects walked without support indoors and four subjects used a stick when walking outdoors.

The mean body mass index calculated as weight/height squared (kg/m^2) was 25.2 ± 3.9 at the first evaluation and 25.6 ± 4.5 7 years later; this change was not significant.

In the present study, the subjects were asked if their general activity level had changed compared with 7 years ago and, if so, whether the increase or decrease was small or large. No increase was found. Six subjects rated the decrease as large. Seven rated the decrease as small. Four subjects judged their general activity level to be unchanged. In the present study 11 subjects reported that they experienced some kind of vertigo or balance problems. At both evaluations the subjects rated vertigo or dizziness on a 100-mm visual analogue scale. The mean was 11.4 ± 16.5 mm at the first evaluation and 22.2 ± 23.0 mm at the 7-year follow-up (p = NS).

Static balance tests

The group had a significantly impaired result in four out of six static balance tests compared with 7 years earlier: sharpened Romberg with eyes open; sharpened Romberg with eyes closed; standing on one leg with eyes open; and standing on one leg with eyes closed. Before the study period, all subjects managed to stand for 30 seconds in Romberg's position with both eyes open and eyes closed. This result was unchanged at follow-up, except for one person who did not manage to stand in Romberg's position with closed eyes (Table III).

Walking tests

The number of correct steps walking forward on one line and backward between two lines had not changed significantly. The time required to walk 30 m had increased significantly from 20.9 ± 2.9 seconds to 23.1 ± 4.3 seconds ($p < 0.01$).

Dynamic posturography

The scores in the SOT had improved significantly in SO 3 ($p < 0.01$). No other scores changed significantly (Table IV).

Table III. *Time in seconds (mean ± SD) the subjects were able to maintain static balance in the different standing positions*

Position	Original study ($n = 17$)	7-year follow-up ($n = 17$)	p
Romberg EO	30.0 ± 0.0	30.0 ± 0.0	1.000
Romberg EC	30.0 ± 0.0	28.7 ± 5.3	0.317
Sharpened Romberg EO	30.0 ± 0.0	22.4 ± 10.7	0.012
Sharpened Romberg EC	19.6 ± 11.1	5.1 ± 6.8	0.001
One leg EO	20.9 ± 11.6	11.5 ± 9.7	0.015
One leg EC	5.1 ± 3.9	1.1 ± 1.9	0.001

EO = eyes open; EC = eyes closed.

Table IV. *Scores (mean ± SD) in the dynamic posturography sensory organization test*

Condition	Original study ($n = 17$)	7-year follow-up ($n = 17$)	p
SO 1	92.9 ± 2.4	92.6 ± 1.7	0.697
SO 2	87.4 ± 8.9	88.8 ± 2.7	0.794
SO 3	83.6 ± 4.6	87.8 ± 5.0	0.007
SO 4	82.5 ± 5.1	78.8 ± 8.3	0.162
SO 5	49.6 ± 26.3	47.9 ± 23.2	0.344
SO 6	52.6 ± 21.7	44.2 ± 28.2	0.187
Composite	70.5 ± 9.7	68.2 ± 12.1	0.147

The backward translations in the motor coordination test showed increased latencies (Table V).

DISCUSSION

There is a need for research concerning how and when different aspects of balance change during ageing.

In the study 7 years earlier subjects voluntarily answered an invitation to participate and only healthy subjects were included. They must therefore be considered as a selected group, more healthy and perhaps with a greater interest in physical training than elderly people in general. The 17 subjects remaining in this follow-up study were a healthy group of 80-year-olds, all living at home.

Eleven of the 17 subjects (65%) described vertigo and balance problems when asked after 7 years. They had doubled their mean visual analogue scale ranking of vertigo and balance problems compared with 7 years ago, but the change was not significant and the mean values fell within the first 25% of the scale both before and after the 7 years.

There are few gold standards for how to perform clinical balance tests in standing. Different authors have described different positions, durations of measurements, numbers of trials and criteria for stopping the time. We accepted compensatory movements of arms or the lifted leg without stopping the time-keeping because we think that most subjects make small adjustments and it is difficult to judge by observation what degree of movements to accept or not accept.

The ability to maintain balance decreases with higher age. The subjects in this study performed the sharpened Romberg's test and one-leg stance for a significantly shorter time compared with 7 years earlier. The subjects could stand on one leg for 11.5 ± 9.7 seconds with their eyes open and for 1.1 ± 1.9 seconds with their eyes closed. These results are in agreement with those of other studies where comparable test procedures and groups of active healthy subjects have been used (1, 25). There were large differences between the eyes-open and eyes-closed conditions in the static balance tests. This implies that vision is very important to the elderly to help maintain balance when proprioceptive and vestibular information is diminished. Obviously, Romberg's test was not difficult enough to reveal differences in our subjects. We conclude that more difficult positions, such as the sharpened Romberg's test and standing on one leg, are needed for assessing static balance in healthy elderly people. Also, the balance tests of walking forward on one line and backward between two lines were obviously too crude to detect differences in this group.

Table V. *Latencies in milliseconds (mean ± SD) of force responses to sudden movements in the dynamic posturography motor coordination test*

Condition	Original study ($n = 17$)	7-year follow-up ($n = 17$)	p
Backward medium	159.4 ± 16.3	167.9 ± 14.9	0.027
Backward large	150.3 ± 17.7	159.1 ± 13.4	0.046
Forward medium	152.9 ± 15.6	152.6 ± 15.4	0.773
Forward large	146.2 ± 17.4	138.8 ± 9.6	0.082

The time required to walk 30 m had increased significantly. In a population study of 79-year-olds, Lundgren-Lindquist et al. (26) found maximum walking speeds of 1.43 m/second in men and 1.18 m/second in women. In the present study, the mean walking speeds were 1.41 m/second for men and 1.30 m/second for women. Our subjects were somewhat older than the subjects of Lundgren-Lindquist et al. and made a 180° turn after 15 m. Their walking speed may therefore be considered to be higher than that for the elderly population in general, as a result of training and/or the selection of healthy subjects.

In a study by Ekdahl et al. (10) a test of walking speed in healthy subjects of different ages was performed in exactly the same way as in our study. In subjects 20–29 years old, the mean speeds were 2.34 m/second for men and 2.29 m/second for women. The mean time for subjects 60–64 years old was 1.94 m/second for men and 1.61 m/second for women. The results for our group of 80-year-olds support the finding by Ekdahl et al. that maximal speed for walking 30 m decreases with normal ageing.

In our group of elderly people the results of dynamic posturography were similar to those of 7 years earlier. Brocklehurst et al. (27) have shown that the increase in sway with age (measured by Wright's Ataxiameter) becomes more obvious above the age of 85 years.

In a dynamic posturography study, Wolfson et al. (28) compared results between three age groups of healthy elderly people: 70–74 years, 75–79 years and ≥80 years. They did not find any significant relationship with age in the SOT. In the MCT part, however, increased latencies in the backward translations were found. In the study by Ledin et al. (20) the exercise group showed significant improvement in SOT but no clear effects of balance training were found in the MCT. Ledin et al. suggested that latencies are merely monitors of the stretch reflexes, nerve impulse transmissions and the time required to activate the muscles around the ankles and are therefore not likely to improve by training. The changes in the MCT and static balance tests seen in our study probably reflect age changes in the functions mentioned above, as well as in central integration capacity of the balance system. The SOT seems to be too crude to detect age changes, or the lack of impairment may be a result of activity and training.

CONCLUSION

In this group of physically active elderly subjects, few changes in body sway in the SOT part of dynamic posturography were seen between 73 and 80 years of age. However, the results from the timed static balance tests in sharpened Romberg position and standing on one leg and from backward translations in the MCT part of dynamic posturography were significantly impaired.

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