Clinical Rehabilitation
http://cre.sagepub.com

Effects of balance training in elderly people with nonperipheral vertigo and unsteadiness

Ann-Sofi C Kammerlind, Jenny K Håkansson and Maria C Skogsberg
Clin Rehabil 2001; 15; 463
DOI: 10.1191/0269215501680425180

Clinical Rehabilitation 2001; **15**: 463–470

Effects of balance training in elderly people with nonperipheral vertigo and unsteadiness

Ann-Sofi C Kammerlind, Jenny K Håkansson and **Maria C Skogsberg** Department of Neuroscience and Locomotion, Division of Oto-Rhino-Laryngology, Linköping University, Sweden

Received 17th November 2000; returned for revisions 4th January 2001; revised manuscript accepted 15th May 2001.

Objective: To evaluate the effect of balance training in group in elderly people with nonperipheral vertigo and unsteadiness.
Design: Randomized controlled study.
Setting: Ear-, nose- and throat department, University Hospital, Sweden.
Subjects: Twenty-three elderly subjects with nonperipheral vertigo and/or unsteadiness randomized into training group and control group.
Intervention: The training group attended balance training in group twice a week for eight weeks.
Main outcome measures: Timed static balance tests, walking tests and six sensory organization tests on EquiTest dynamic posturography were performed before and after the training period. Besides, the patients estimated their vertigo and unsteadiness on a visual analogue scale (VAS) before and after the training period.
Results: The training group improved significantly in standing on one leg with eyes open, walking forward on a line, walking speed, in three out of six tests on dynamic posturography and estimated less vertigo and unsteadiness measured with VAS. No changes were seen in the control group.
Conclusion: Balance training in elderly people with nonperipheral vertigo and unsteadiness seems to improve both objective and perceived balance.

Introduction

To maintain balance, vestibular, visual and somatosensory information is continuously processed in the central nervous system. Postural muscles are activated by both reflex mechanisms and voluntary postural movements to keep the centre of gravity within the limits of stability. Because of age-related changes in the balance system, age-related diseases and inactivity, the postural control decreases with increased age.[1–3] Impaired balance is related to the increase of falls, fractures and other fall-related injuries in older persons.[4–6]

Vertigo and unsteadiness are common complaints among elderly people. Colledge *et al.*[7] sent a questionnaire to subjects over the age of 65, all living in their private homes in Scotland. Thirty per cent reported dizziness and 80% of those had had their symptoms for more than six months. Severe symptoms were significantly

Address for correspondence: Ann-Sofi Kammerlind, Department of Neuroscience and Locomotion, Division of Oto-Rhino-Laryngology, Linköping University, S-581 83 Linköping, Sweden. e-mail: anngu@inr.liu.se

0269–2155(01)CR436OA

correlated with higher age.

In the USA, 24% of community-living persons 72 years and older reported dizziness in a study by Tinetti *et al*.[8] Sixt *et al*.[9] studied 75-year-olds in Sweden. Thirty per cent of the men and 40% of the women experienced vertigo or balance problems. Unsteadiness was more common than rotational vertigo. Head movements, walking and change of position were the most common provoking factors. Chronic dizziness has been found to be associated with risk of falling in elderly people.[10]

Vertigo is defined as hallucinations of movement. Unsteadiness is defined as a subjective experience of poor balance. Central or nonperipheral vertigo in elderly people often results from diverse and complex mechanisms. A common cause is insufficient vascular supply to the brainstem and cerebellum. Our experience is that vertigo and balance problems often lead to inactivity that causes increased symptoms; this constitutes a vicious circle.

Most of the elderly people studied to date in relation to balance training have been either healthy or fallers. Johansson and Jarnlo[11] randomized 34 healthy 70-year-old women to a control group and a training group. The latter group received balance training for one hour twice a week for five weeks and improved significantly in six out of nine clinical balance tests. No significant differences were found in the control group. Ledin *et al*.[12] studied 30 healthy elderly subjects aged 70–75 years and randomized them into an exercise group and a control group. The exercise group attended balance training twice a week for nine weeks. Dynamic posturography and clinical balance tests were performed before and after the nine weeks. The exercise group showed significant improvement in clinical tests, such as standing on one leg with eyes closed, standing on one leg while shaking the head and walking 30 m. The exercise group also improved significantly in three out of six conditions in dynamic posturography. The control group improved significantly only in one dynamic posturography test condition. Shumway-Cook *et al*.[13] evaluated the effects of individualized exercise programmes in elderly people with a history of falls. Exercises were performed twice a week in a physical therapy department and daily at home for 8–12 weeks. They found significant improvement in clinical tests of balance and mobility, and fall risk.

The present study was designed to evaluate the effect of balance training twice a week for eight weeks in balance tests, walking speed and self-rating of symptoms in elderly people with vertigo and unsteadiness caused by disturbances in the central nervous system.

Methods

Subjects

The study group comprised elderly persons with nonperipheral vertigo and/or unsteadiness who had not taken part in any training because of these symptoms, and who were able to attend balance group training. Over two years, 303 people 65 years or older had been investigated with electronystagmography and dynamic posturography at the ENT department of the University Hospital in Linköping, Sweden. One hundred and forty-six people were excluded due to distant habitation. Three people had died. After studying the medical files of the remaining 154 people, another 87 were excluded for the following criteria: blindness, psychiatric disease, acoustic neurinoma, Ménière's disease, peripheral vestibular loss, previous vestibular rehabilitation or other balance training, or only episodic symptoms of vertigo and/or unsteadiness. Questionnaires were sent to the remaining 67 subjects with questions about if they still had symptoms of vertigo and/or unsteadiness, if they used walking aids indoors or outdoors, if they had taken part in vestibular rehabilitation or other balance training, and if they agreed to participate in the study. Fifty-eight of them (86.6%) returned the questionnaires. Another 34 subjects were excluded. The remaining 24 subjects were informed about the study and written consent was obtained from all subjects. They were randomized to exercise group and control group, using 24 sealed envelopes specifying the group (trial or control). One subject in the exercise group was diagnosed with Ménière's disease during the study and was therefore excluded (see Figure 1).

Table 1 shows the characteristics of the 23 subjects. All basic characteristics were equal for the two groups and they did not differ significantly in any of the balance parameters before the study period.

All subjects were still living in their own homes. None of the subjects used walking aids indoors or outdoors. A majority of the subjects described both unsteadiness and attacks of vertigo. About half of the subjects in each group experienced vertigo every day. Two subjects in each group had a diagnosed infarction in the brainstem or cerebellum.

Assessment

The present study was similar in design to the study of healthy elderly described by Ledin *et al.*[12] This was done to make comparisons possible. Some modifications were made in the assessment procedure. To increase the precision in the static balance tests and the walking tests the mean of three trials was used, as in the study of Iverson *et al.*,[14] instead of the best result as used in the study by Ledin *et al.* When walking 15 steps on and between lines Ledin *et al.* noted the number of subjects using incorrect steps. In the present study the number of correct steps for each subject was noted to get values more receptive to change.

A questionnaire with baseline characteristics

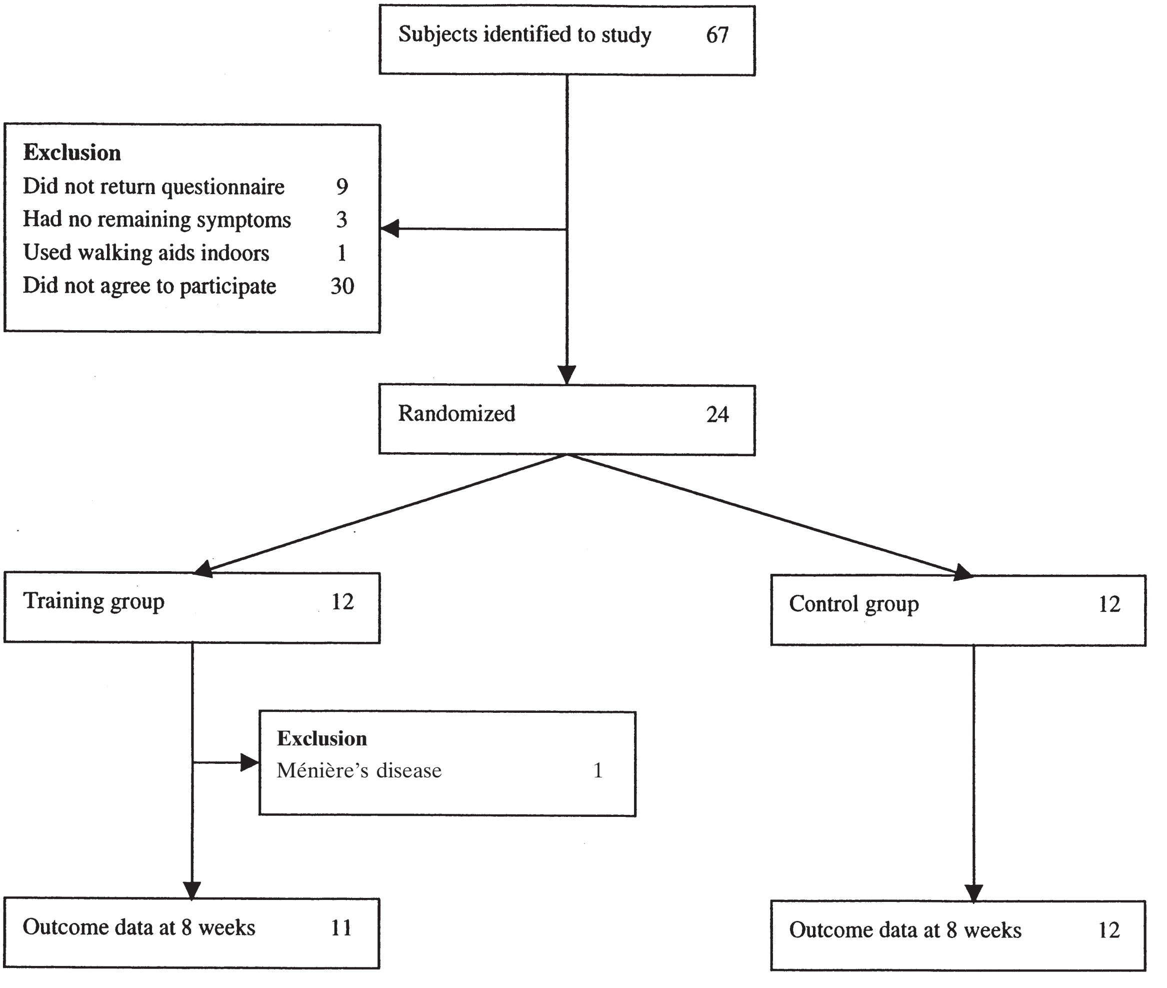

Figure 1 Flow of patients through the study

Table 1 Characteristics of the subjects

Characteristics	Exercise group (n = 11)	Control group (n = 12)
Age (years) mean (SD)	71.5 (4.3)	71.8 (3.5)
No. of females : males	6 : 5	7 : 5
Body Mass Index (kg/m^2) mean (SD)	27.6 (4.4)	25.5 (4.7)
Daily medicines (yes : no)	7 : 4	9 : 3
Subjective vision (good : bad)	10 : 1	10 : 2
Subjective hearing (good : bad)	7 : 4	8 : 4
Type of work before retiring (no. of subjects):		
Mostly sitting	5	2
Mostly standing and walking	3	4
Standing, walking and lifting	3	4
Heavy work	0	2
Habits of physical training (no. of subjects):		
No training	0	1
Irregular soft training	2	3
Regular soft training	5	6
Regular fitness training	3	0
Regular hard training	1	2
History of falling during the last year (yes : no)	5 : 6	6 : 6
Injury or surgery in arm or leg (yes : no)	4 : 7	4 : 8
Duration of symptoms (no. of subjects):		
Less than 1 year	0	2
1–4 years	7	6
5–10 years	1	1
More than 10 years	3	3

was completed before the study period. Subjective rating of vertigo and unsteadiness measured on a closed visual analogue scale, static balance tests, walking tests and dynamic posturography were performed in both the exercise and the control group in the week before and after the training period. The subjects were naïve to the tests conducted. Because of limitations of resources the assessment was not made by an observer blind to which group the subjects belonged to. However, pretreatment values were not looked at until post-treatment values had been collected to counteract observer bias.

Subjective rating of vertigo and unsteadiness

The subjects rated their degree of vertigo and unsteadiness using a 100 mm closed visual analogue scale (VAS) ranging from no symptoms (0 mm) to the worst possible symptoms (100 mm).

Static balance tests

The number of seconds that the subjects could stand with different foot positions with eyes open and eyes closed, respectively, was measured. The mean of three trials was used for analysis. For safety, the subjects stood with a corner 50 cm behind them and the investigator stood in front of the subject. The positions 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. In the eyes closed conditions posture was assumed just prior to eye closure. Arms were held vertically by the sides of the body. The tasks were timed with a stopwatch until the subject moved his feet from the given position, opened his eyes on the eyes closed tests, or reached the maximum time of 30 seconds. Three trials were performed if a maximum of 30 seconds was not reached in the first or second trial. Compensatory movements of arms or the lifted leg were accepted without stopping the time-keeping, but the timing was stopped if the lifted foot touched the floor. Both right and left leg stance was tested, and the result of the best leg was used for analysis. Franchignoni *et al.*[15] have found good interrater (ICC 0.95–0.99) and test–retest (ICC 0.73–0.93) reliability for sharpened Romberg and one leg stance test.

Walking tests

Subjects performed a tandem walk of 15 steps forward along a line 1.5 cm wide, with a colour contrasting to the floor. The number of correct steps was counted. A correct step was defined as a step on the line, with heel to toe not visibly separated. They also walked 15 steps backwards between two lines 20 cm apart. A correct step was defined as a step not touching the lines, with heel to toe not visibly separated. The mean of three trials was used for analysis.

The subjects were also asked to walk 30 m once as fast as possible with shoes on, making a turn of 180° after 15 m, and time was measured in seconds. This test has been used for healthy elderly subjects by Ekdahl *et al.*[16]

Dynamic posturography

Subjects were tested on a computerized dynamic posturography platform (Equitest, Neurocom Int Inc, Clackamas, OR, USA) with a sensory organization test (SOT).[17] In the SOT the three sensory components of balance were assessed under two different support conditions and three different visual conditions. The support surface was fixed in conditions 1–3, and sway referenced (swayed with the subject) in conditions 4–6. The visual surround was fixed in conditions 1 and 4, absent (eyes closed) in conditions 2 and 5, and sway referenced in conditions 3 and 6. The contribution of each sense to maintain balance could be measured when other senses were absent or provided with conflicting information. The subject's body sway was monitored by pressure-sensing strain gauges in the platform and postural stability was measured during a 20-s trial. A score of 100 represented no sway and a score of 0 represented maximum sway (12°) or a fall. Two trials were made in conditions 1–2, and three trials in conditions 3–6. The weight was measured by the platform and the height was measured before the testing. Ford-Smith *et al.*[18] have found poor (in condition 3) to good one-week test–retest reliability of the SOT.

Intervention

The exercise group received mainly balance training in a group exercise session of one hour twice a week for eight weeks. The training started with 15 minutes of warming up exercises in standing and walking with different combinations of arm, trunk, leg and head movements. Twenty-five minutes were devoted to balance training in pairs at different stations: balance and jumping exercises on a trampoline, standing on foam with eyes closed and standing on balance discs doing head movements, ball games, walking exercises on soft and uneven surfaces, walking exercises slalom between cones and strengthening exercises for the legs. Then followed 10 minutes of exercises for balance, strength and flexibility on the floor and finally a few minutes of relaxing and stretching. The programme was accompanied by music. The degree of difficulty of the exercises was increased during the training period as the subjects' balance improved.

The attendance was good; the subjects participated as a mean in 14 ± 2 out of 16 sessions.

The control subjects did not receive any kind of training and were supposed to live as usual. They were offered the opportunity to attend a balance training group after the study period.

Statistical analysis

The Wilcoxon signed rank sum test was used to analyse changes within groups. Differences between the two groups before and after the study period as well as the change were analysed with the Mann–Whitney *U*-test. A significance level of $p \leq 0.05$ was used.

Results

In the static balance tests and walking tests the exercise group improved significantly during the training period in the tests standing on one leg with eyes open, walking forward on a line and walking 30 m as fast as possible. No improvement was seen in the control group. The difference in change between groups was significant for standing on one leg with eyes open (see Table 2).

Concerning Romberg's test with eyes open or closed only four subjects needed more than one trial once during the study. No difference was seen within or between groups.

After the study period the exercise group rated significantly less vertigo and unsteadiness on the VAS than before. No change was seen in the control group. The difference in change between groups was significant (see Table 2).

The scores in SOT in dynamic posturography improved significantly in conditions 3, 4 and 6 in the exercise group. There were no significant changes in the control group. The difference in change between groups were significant for conditions 1, 3, 4 and 6 (see Table 3).

Discussion

Previous studies have shown positive effects of balance training in healthy elderly people.[11,12] Elderly people with vertigo and balance problems have a higher risk of falls than healthy elderly people.[4–6,10] Therefore we consider it important to study effects of balance training in elderly people with vertigo and unsteadiness, in this study caused by disturbances in the central nervous system.

Areas of weakness in the study are the relatively small study sample and the fact that the observers were not blind to the subject's group. A long-term follow-up period would have been desirable.

Table 2 Results in static balance tests, walking tests and subjective rating of vertigo and unsteadiness

Test		Exercise group (n = 11)			Control group (n = 12)			
		Mean	(SD)	p-value[a]	Mean	(SD)	p-value[a]	p-value[b]
Sharpened Romberg EO (seconds)	Pretest	23.6	(10.6)		24.6	(7.5)		0.976
	Post-test	22.6	(9.1)	0.499	22.5	(10.2)	0.735	0.878
	Change	–1.0	(5.3)		–2.2	(11.2)		**0.424**
Sharpened Romberg EC (seconds)	Pretest	8.3	(8.3)		9.9	(10.7)		0.735
	Post-test	13.8	(10.5)	0.051	9.4	(10.6)	0.722	0.196
	Change	+5.5	(7.4)		–0.5	(5.6)		**0.056**
One leg EO (seconds)	Pretest	12.4	(11.6)		10.3	(8.7)		0.951
	Post-test	19.1	(12.2)	0.011*	10.7	(9.4)	0.875	0.124
	Change	+6.6	(8.4)		+0.4	(6.9)		**0.036***
One leg EC (seconds)	Pretest	2.6	(1.2)		2.1	(0.7)		0.460
	Post-test	2.9	(2.0)	0.722	2.1	(0.7)	0.938	0.356
	Change	+0.3	(1.4)		0.0	(0.9)		**0.878**
Walking forward on a line (no. of correct steps)	Pretest	12.5	(2.9)		13.0	(1.9)		0.782
	Post-test	14.0	(2.0)	0.008**	13.2	(1.5)	0.441	0.097
	Change	+1.4	(2.1)		0.0	(1.6)		**0.230**
Walking backward between lines (no. of correct steps)	Pretest	11.6	(3.2)		11.7	(1.8)		0.559
	Post-test	12.0	(2.5)	0.260	11.4	(2.2)	0.845	0.424
	Change	+0.4	(1.3)		–0.3	(2.4)		**0.644**
30-m walking test (seconds)	Pretest	22.9	(3.2)		22.5	(3.8)		0.712
	Post-test	21.5	(3.3)	0.003**	21.9	(2.6)	0.327	0.667
	Change	–1.4	(1.1)		–0.6	(1.8)		**0.110**
Visual analogue scale (mm)	Pretest	42.5	(28.7)		40.0	(23.6)		0.951
	Post-test	22.3	(21.8)	0.003**	38.3	(26.3)	0.784	0.166
	Change	–20.2	(25.5)		–1.7	(36.2)		**0.046***

EO, eyes open; EC, eyes closed.
[a]Within-group analysis.
[b]Between-group analysis.
Figures in bold are the p-values for the difference in change between groups.
*$p < 0.05$; **$p < 0.01$.

Table 3 Scores in dynamic posturography, sensory organization test

Condition		Exercise group (n = 11)			Control group (n = 12)			
		Mean	(SD)	p-value[a]	Mean	(SD)	p-value[a]	p-value[b]
1	Pretest	93.0	(3.4)		93.9	(1.7)		0.951
	Post-test	93.5	(1.8)	0.799	92.5	(2.1)	0.071	0.295
	Change	+0.5	(2.4)		–1.4	(2.4)		**0.049****
2	Pretest	89.2	(3.4)		87.8	(5.9)		0.712
	Post-test	89.5	(2.7)	0.674	88.8	(4.6)	0.410	0.854
	Change	+0.2	(2.3)		+0.9	(3.0)		**0.902**
3	Pretest	87.2	(3.0)		88.8	(4.8)		0.356
	Post-test	89.0	(3.4)	0.013*	87.8	(4.5)	0.286	0.559
	Change	+1.8	(1.8)		–1.0	(3.7)		**0.011***
4	Pretest	78.3	(7.0)		83.1	(4.9)		0.061
	Post-test	83.2	(6.3)	0.011*	79.2	(8.9)	0.077	0.356
	Change	+4.9	(4.7)		–3.8	(6.4)		**0.002****
5	Pretest	51.0	(21.9)		55.1	(14.2)		1.000
	Post-test	63.5	(5.6)	0.286	58.3	(15.2)	0.213	0.735
	Change	+12.6	(22.4)		+3.2	(8.3)		**0.758**
6	Pretest	49.9	(12.9)		58.1	(17.3)		0.103
	Post-test	58.5	(16.3)	0.041*	56.6	(14.5)	0.583	0.479
	Change	+8.6	(11.2)		–1.6	(12.5)		**0.049***

[a]Within-group analysis.
[b]Between-group analysis.
Figures in bold are the p-values for the difference in change between groups.
*$p < 0.05$; **$p < 0.01$.

Clinical messages

- Balance training in elderly people with nonperipheral vertigo and/or unsteadiness seems to improve both objectively measured and perceived balance.
- The standard Romberg test was too easy and standing on one leg with eyes closed too difficult for elderly people with vertigo and unsteadiness. The sharpened Romberg test and standing on one leg with eyes open proved to be most appropriate as clinical static balance tests for this study sample.

None of the subjects included had received any specific training aimed at reducing vertigo or improving balance before this study. This may explain the generally high motivation and good attendance in the exercise group. Performing balance exercises at different stations worked well in our study sample because it made it possible to adjust the level of difficulty according to each subject's possibilities.

The subjects in the exercise group improved in the balance tests standing on one leg with eyes open and walking forward on a line. Healthy elderly people described by Ledin *et al.*[12] improved in one leg stance with eyes closed, but not with eyes open. In the SOT in dynamic posturography the healthy elderly subjects swayed less in conditions 4, 5 and 6 after training,[12] while in this study improvements were seen in conditions 3, 4 and 6. Both this study sample and the healthy elderly subjects described by Ledin *et al.*[12] improved in the 30-m walking test. The subjects in this study were somewhat younger than those in the study described by Ledin *et al.*,[12] but nevertheless they had lower gait speed. This suggests that balance problems might influence walking speed. In the exercise group only one subject in this study performed regular conditioning exercises before the training period. Therefore, one might assume that the improved walking speed was a result of increased strength and fitness as well as balance.

Concerning the clinical balance tests there were ceiling and floor effects in the data for some of the tests. The standard Romberg test was too easy even for the study sample. On the other hand standing on one leg with eyes closed proved to be too difficult. Sharpened Romberg and standing on one leg with eyes open proved to be the most appropriate clinical static balance tests for this study sample.

Stones and Kozma[19] found that standing on one leg with eyes open had greater sensitivity to the effects of physical training than the eyes closed condition. Johansson and Jarnlo[11] trained healthy 70-year-old women and found significant improvement in standing on one leg with eyes open but not with eyes closed. Our study confirmed these results.

Neither in the clinical balance tests nor in the dynamic posturography were any significantly improved results found in the conditions with eyes closed. At least in our study this difference can partly be explained by the fact that the exercise group performed most of the training sessions with eyes open, enhancing the integration of the visual, vestibular and somatosensory systems.

We think there is reason to believe that improved balance for elderly persons with vertigo can initiate positive effects on physical activity levels due to decreased fear and increased self-confidence.

Acknowledgements

This study was supported by a grant from the Federation of County Councils in Sweden. We are grateful of the assistance of Torbjörn Ledin, Elisabeth Skargren and Lars Ödkvist in preparing the manuscript.

References

1 Konrad HR, Girardi M, Helfert R. Balance and aging. *Laryngoscope* 1999; **109**: 1454–60.
2 Alexander NB. Postural control in older adults. *J Am Geriatr Soc* 1994; **42**: 93–108.
3 Maki BE, McIlroy WE. Postural control in the older adult. *Clin Geriatr Med* 1996; **12**: 635–58.
4 Gehlsen GM, Whaley MH. Falls in the elderly: part 2, balance, strength and flexibility. *Arch Phys Med Rehabil* 1990; **71**: 739–41.
5 Shumway-Cook A, Baldwin M, Polissar NL. Predicting the probability for falls in community-dwelling older adults. *Phys Ther* 1997; **77**: 812–19.
6 Tinetti ME, Williams SF, Mayewski R. Fall risk index for elderly persons living in the community. *N Engl J Med* 1986; **80**: 429–34.
7 Colledge NR, Wilson JA, Macintyre CCA, MacLennan WJ. The prevalence and characteristics of dizziness in an elderly community. *Age Ageing* 1994; **23**: 117–20.
8 Tinetti ME, Williams CS, Gill TM. Dizziness among older adults: A possible geriatric syndrome. *Ann Intern Med* 2000; **132**: 337–44.
9 Sixt E, Landahl S. Postural disturbances in a 75-year-old population: 1. Prevalence and functional consequences. *Age Ageing* 1987; **16**: 393–98.
10 Tinetti ME, Williams CS, Gill TM. Health, functional, and psychological outcomes among older persons with chronic dizziness. *J Am Geriatr Soc* 2000; **48**: 417–21.
11 Johansson G, Jarnlo G-B. Balance training in 70-year-old women. *Physiother Theory Pract* 1991; **7**: 121–25.
12 Ledin T, Kronhed AC, Möller C, Möller M, Odkvist LM, Olsson B. Effects of balance training in elderly people evaluated by clinical tests and dynamic posturography. *J Vestib Res* 1991; **1**: 129–38.
13 Shumway-Cook A, Gruber W, Baldwin M, Liao S. The effect of multidimensional exercises on balance, mobility, and fall risk in community-dwelling older adults. *Phys Ther* 1997; **77**: 46–57.
14 Iverson BD, Gossman MR, Shaddeau SA, Turner MEJ. Balance performance, force production, and activity levels in noninstitutionalized men 60 to 90 years of age. *Phys Ther* 1990; **70**: 348–55.
15 Franchignoni F, Tesio L, Martino MT, Ricupero C. Reliability of four simple, quantitative tests of balance and mobility in healthy elderly females. *Aging (Milano)* 1998; **10**: 26–31.
16 Ekdahl C, Jarnlo G-B, Andersson SI. Standing balance in healthy subjects. *Scand J Rehabil Med* 1989; **21**: 75–83.
17 Ledin T. Dynamic posturography in evaluating human equilibrium. Thesis, Linköping Health University, Linköping, Sweden, 1991.
18 Ford-Smith CD, Wyman JF, Elswick RK Jr, Fernandez T, Newton RA. Test–retest reliability of the sensory organization test in noninstitutionalized older adults. *Arch Phys Med Rehabil* 1995; **76**: 77–81.
19 Stones MJ, Kozma A. Balance and age in the sighted and blind. *Arch Phys Med Rehabil* 1987; **68**: 85–89.