Archives of Gerontology and Geriatrics 48 (2009) 22–27

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Effects of risk-based multifactorial fall prevention on postural balance in the community-dwelling aged: A randomized controlled trial

Marika Salminen [a,*], Tero Vahlberg [b], Sanna Sihvonen [c], Noora Sjösten [a], Maarit Piirtola [a,d], Raimo Isoaho [a,e,f], Pertti Aarnio [g], Sirkka-Liisa Kivelä [a,g,h]

[a] Institute of Clinical Medicine, Department of Family Medicine, Lemminkäisenkatu 1, University of Turku, FI-20014 Turku, Finland
[b] Institute of Clinical Medicine, Department of Biostatistics, Lemminkäisenkatu 1, University of Turku, FI-20014 Turku, Finland
[c] National Public Health Institute, Mannerheimintie 166, FI-00300 Helsinki, Finland
[d] Lieto Health Centre, Hyvättyläntie 7, FI-21420, Finland
[e] Pori Health Centre, Maantiekatu 31, FI-28600 Pori, Finland
[f] Nordic School of Public Health, Nya Varvet, Building 25, SE-40242 Gothenburg, Sweden
[g] Satakunta Central Hospital, Sairaalantie 3, FI-28500 Pori, Finland
[h] Unit of Family Medicine, Turku University Hospital, Kiinamyllynkatu 4-8, FI-20520 Turku, Finland

ARTICLE INFO

Article history:
Received 6 June 2007
Received in revised form 3 September 2007
Accepted 6 September 2007
Available online 24 October 2007

Keywords:
Multifactorial fall prevention
Postural control
Postural balance measures

ABSTRACT

The purpose of the study was to assess the effects of 12-month risk-based multifactorial fall prevention program on postural control of the aged. Five hundred and ninety-one (97%) eligible subjects were randomized into an intervention group (IG) ($n = 293$) and a control group (CG) ($n = 298$). The effects of the program were measured on standing, dynamic, and functional balance.

In standing balance, the velocity moment of semi-tandem standing decreased in IG (median change -0.54 mm^2/s) but increased in CG (+3.84 mm^2/s) among all women ($p = 0.011$) and among the women aged 65–74 years (-1.65 mm^2/s and +2.80 mm^2/s, correspondingly) ($p = 0.008$). In a dynamic test, performance distance tended to decrease in IG (-26.54 mm) and increase in CG (+34.10 mm) among all women ($p = 0.060$). The women aged 75 years or over, showed marginally significant differences between the groups as regards changes in performance time (-2.66 s and -0.90 s) ($p = 0.068$) and distance (-92.32 mm and +76.46 mm) ($p = 0.062$) of the dynamic balance test in favor of IG. Men showed no significant differences in the changes between the groups in any balance measures.

1. Introduction

Falls and unstable balance are common serious clinical problems among aged people. A pooled data set demonstrated that the major risk factors for falls are muscle weakness and deficits in balance and gait (Rubenstein, 2006). Multifactorial interventions are consistent with the generally multifactorial causation of falls (Gillespie et al., 2003).

Randomized controlled exercise interventions to reduce falls and the risk factors for falling have been successful in improving the balance of aged people with high risk for falling (Barnett et al., 2003; Brouwer et al., 2003; Song et al., 2003; Nitz and Low Choy, 2004), while others have not (Rubenstein et al., 2000; Latham et al., 2003; Lord et al., 2003; Steadman et al., 2003). Only a few randomized controlled multifactorial fall prevention studies including assessment of the effects of the intervention on postural control have been conducted among the community-dwelling aged. A study performed among aged subjects with at least one risk factor for falling showed a significant reduction of persons with balance impairment at follow-up compared to the baseline (Tinetti et al., 1994). A study carried out among community-dwelling aged persons without specified risk factors for falling also showed significant improvement in functional balance (Yates and Dunnagan, 2001).

The purpose of this study was to assess the effects of randomized controlled 12-month risk-based multifactorial fall prevention on the standing, dynamic, and functional balance of the aged. We also investigated whether the effects on postural control differ by gender and age.

2. Methods

2.1. Subjects

This study is part of a fall prevention trial among the aged living in Pori, Finland. Details regarding the design and methodology of the trial have been reported elsewhere (Sjösten et al., 2007).

* Corresponding author. Tel.: +358 2 333 8429; fax: +358 2 333 8439.
E-mail address: majosa@utu.fi (M. Salminen).

0167-4943/$ – see front matter © 2007 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.archger.2007.09.006

Briefly, the inclusion criteria were: age 65 years or over, at least one fall during the previous 12 months, Mini Mental State Examination ≥17, able to walk 10 m independently with or without walking aids, and living at home or in sheltered housing. Persons willing to participate and fulfilling the inclusion criteria (n = 591) (97% of those interviewed by a geriatrician) were randomly assigned into an intervention group (IG) (n = 293) and a control group (CG) (n = 298). The subjects were randomized separately in two age groups (65–74 and ≥75 years) after the baseline assessment using consecutively numbered sealed envelopes.

2.2. Balance measurements

Balance measurements in both groups were completed at baseline and after 1 year. The measurements were done by two trained physiotherapists. The follow-up measurements were non-blinded. Balance was measured using the Good Balance® system (Metitur, Finland) consisting an equilateral triangular force platform connected to a computer. The following measurements were carried out with subject standing on the force platform: (1) normal standing for 30 s with eyes open, hands hanging down loosely, feet comfortably apart, and gaze fixed on a mark (a cross on the opposite wall at 2 m) at eye level; (2) normal standing as above for 30 s but with eyes closed; (3) semi-tandem (the first metatarsal joint of one foot besides the other foot's calcaneus) standing for 20 s with eyes open, hands hanging down loosely and gaze fixed on a mark as before. The tests were performed three times in the same order for every subject, starting with the easiest test and advancing to the more difficult tests. One trial for the tests 1 and 2 and two trials for test 3 were done first. These three tests are referred to as "standing balance tests".

For movement of the centre of pressure, three balance outcome variables were calculated for all standing balance tests: anteroposterior sway velocity, mediolateral sway velocity, and velocity moment, which refers to the first moment of velocity calculated as the mean area covered by the movement of the centre of pressure during each second of the test, taking into account both the distance from the geometrical midpoint of the test and the speed of movement during the same period (Era et al., 1996). The lowest value of the velocity moment was used as an indicator to choose the test for the analysis. The effects of body height were compensated for by adjusting the absolute sway measures of anteroposterior and mediolateral sway velocity according to the height ([sway variable/subject's height in cm] × 180) (Era et al., 1996). In the velocity moment, the effect of body height was compensated for according to the following formula: sway variable/subject's height in $cm^2 \times 180^2$.

In the dynamic balance test the subjects were asked to move their center of pressure along a track shown on a computer screen. The target arrangements of the test are shown in Fig. 1. The performance time (time used to complete the test) and the distance (the extent of the path traveled by the centre of pressure during the test) were measured. The test with the shortest performance time of five repetitions was entered in to the analysis.

The Berg Balance Scale (BBS) (Berg et al., 1989) was used as a functional balance measure. The other measurements done are presented elsewhere (Sjösten et al., 2007).

2.3. Intervention for fall prevention

The 12-month fall prevention program was based on an individual risk factor analysis and it was customized to suit each participant's health. The details of the program have been described elsewhere (Sjösten et al., 2007). The intervention consisted of an individual geriatric assessment, individual counseling and guidance in fall prevention, home hazards assessment, group physical exercise, lectures, psychosocial activity groups, and home exercise. The subjects were divided into three exercise groups according to their physical functional abilities. Exercise was done in groups of 4–10 participants every second week under the guidance of a physiotherapist. Each session (45–50 min) began with warming up (5 min), including brisk walking and upper body movements. Balance, coordination, and weight-shifting exercises (15 min) included standing on one foot, toes, and heels, semi-tandem stance and squat, tandem stance and squat, reaching forward, bending down, marching in place lifting the knees, and walking exercises such as heel-toe walking, walking backward, stepping sideward, walking the figure of eight, and tandem walking. Circuit training for muscle strength (20 min) included training of the lower extremities (hip and knee extensors and flexors, ankle plantar and dorsal flexors) and the abdominal and back muscles using the participants' body weight. Muscle strength training consisted of sit-to-stand, one-leg squat, and toe and heel rises. Each exercise was performed for 45 s, and the cooling time between the exercises was about 30 s, including the transition from one exercise to another. Two to four circuits were performed with 3–5-min cooling between the circuits. Cool-down (5–10 min) included stretching of the trained muscle groups and relaxation exercises. The intensity of the sessions was increased progressively (levels 1–4) according to the subjects' fitness level. The intensity was measured after each session by the Borg Rating of Perceived Exertion Scale (Borg, 1998). Exercises could be performed by holding onto a rail if necessary due to the participants' health. The use of the rail was gradually minimized during the intervention.

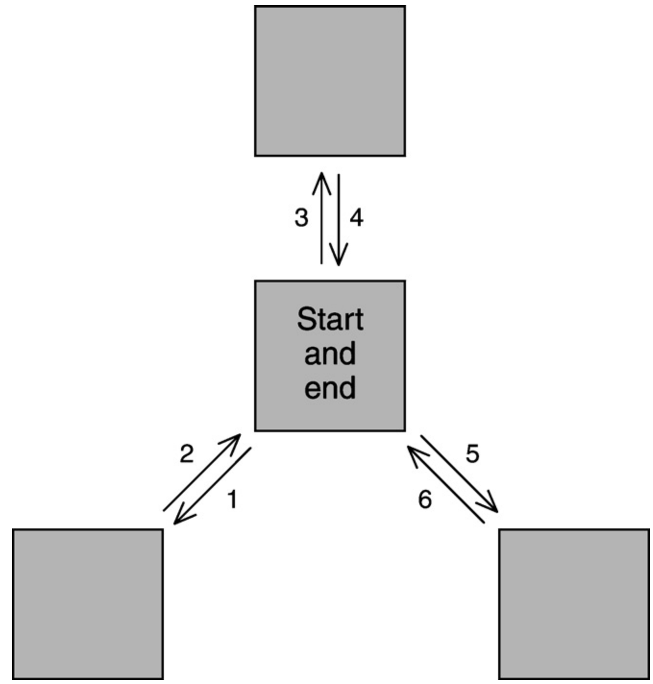

Fig. 1. Center of pressure target arrangements for the dynamic test. Subjects were asked to move their center of pressure along a track shown on a computer screen.

The subjects were advised to perform physical exercises similar to those performed in groups three times a week at home. The subjects got written information based on the content of the group exercise sessions and were encouraged to record their daily physical activity in exercise diaries.

The subjects in CG attended one session of counseling and guidance on specified risk factors of falling during the 12-month follow-up.

2.4. Ethics

The study was conducted according to the guidelines of the Declaration of Helsinki. The Ethics Committee of Satakunta Hospital District approved the study protocol. The participants gave informed consent.

2.5. Data analyses

A total of 66 subjects dropped out (37 in IG and 29 in CG) during the follow-up of 12 months. The main reasons were health problems ($n = 18$), death ($n = 9$), dissatisfaction with the study ($n = 2$), and motivational ($n = 2$) or financial reasons ($n = 2$). Subjects with baseline and follow-up data of at least one balance measurement were included in the analyses ($n = 525$) (89% of those eligible). Of the 525 subjects, 256 (37 men and 219 women) belonged to IG and 269 (49 men and 220 women) to CG.

The data were analyzed on an intention-to-treat analysis basis. The differences in the demographic variables between IG and CG were analyzed using the chi-square test, Fisher's exact test or Mann–Whitney *U*-test. Kolmogorov–Smirnov's test was used to test the normality of distributions.

Mann–Whitney *U*-test was used to test the differences in balance outcome variables between the groups at baseline and in the changes between the groups during the follow-up. Firstly, the differences in changes were analyzed for all men and women. Secondly, corresponding analyses were performed in the two age groups (65–74 and ≥75 years) of men and women. *p*-Values less than 0.05 were considered statistically significant and *p*-values between 0.05 and 0.080 marginally significant. Data are expressed as median and lower quartile–upper quartile. SAS System for Windows, version 9.1 (SAS Institute Inc., Cary, NC) was used in statistical analyses.

3. Results

3.1. Dropout analysis

Among men, there was a marginally significant difference between those who completed the study ($n = 86$) and those who dropped out (for reasons other than death) ($n = 7$) in BBS (53.0, 49.0–54.0 and 46.0, 31.0–52.0, correspondingly) ($p = 0.060$). Eighty-four percent of men completing the study lived with a spouse or another person and 16% lived alone, while the corresponding proportions among the male drop-outs were 29% and 71% ($p = 0.004$).

Among women, there were significant differences between those who completed the study ($n = 439$) and the drop-outs ($n = 50$) in median age (72.0, 68.0–76.0 and 77.0, 73.0–84.0) ($p < 0.001$), Mini Mental State Examination (28.0, 26.0–29.0 and 27.0, 25.0–28.0) ($p = 0.006$), GDS (4.0, 1.0–8.0 and 5.0, 2.0–13.0) ($p = 0.045$), managing the activities of daily living (32.0, 31.0–32.0 and 29.0, 23.0–32.0) ($p < 0.001$), and BBS (53.0, 50.0–55.0 and 47.5, 38.0–52.0) ($p < 0.001$) in favor of those who completed the study.

Table 1
Baseline characteristics of the participants ($n = 525$) in the intervention ($n = 256$) and control groups ($n = 269$), by gender

	Intervention group		Control group	
	Men, $n = 37$, n (%)	Women, $n = 219$, n (%)	Men, $n = 49$, n (%)	Women, $n = 220$, n (%)
Age[a] (years)	72.0 (69.0–76.0)	72.0 (68.0–76.0)	74.0 (70.0–77.0)	71.5 (68.0–76.0)
Age				
<75 years	24 (65)	143 (65)	28 (57)	150 (68)
≥75 years	13 (35)	76 (35)	21 (43)	70 (32)
Marital status				
Married or co-habiting	29 (78)	83 (38)	40 (82)	95 (43)
Single	3 (8)	14 (6)	1 (2)	16 (7)
Widowed, divorced or judicial separation	5 (14)	122 (56)	8 (16)	109 (50)
Living place				
Home	36 (100)	211 (96)	49 (100)	205 (93)
Sheltered housing	0 (0)	8 (4)	0 (0)	15 (7)
Living circumstances				
Living with a spouse or another person	32 (86)	85 (39)	40 (82)	98 (45)
Living alone	5 (14)	134 (62)	9 (18)	122 (55)
Education				
More than basic	10 (27)	62 (28)	7 (14)	65 (30)
Basic	26 (70)	155 (71)	41 (84)	153 (70)
Less than basic	1 (3)	2 (1)	1 (2)	2 (1)
Use of walking aids				
No	33 (89)	180 (82)	39 (80)	183 (83)
Yes	4 (11)	39 (18)	10 (20)	37 (17)
Use of prescribed medication				
<4	15 (41)	112 (51)	28 (57)	122 (55)
≥4	22 (59)	107 (49)	21 (43)	98 (45)
MMSE[a]	28.0 (27.0–29.0)	28.0 (26.0–29.0)	27.0 (26.0–29.0)	28.0 (26.0–29.0)
GDS[a]	3.0 (2.0–7.0)	4.0 (2.0–8.0)	3.0 (1.0–6.0)	4.0 (1.0–8.0)
ADL[a,b]	31.0 (31.0–32.0)	32.0 (30.0–32.0)	32.0 (31.0–32.0)	32.0 (31.0–32.0)

No statistically significant differences between the groups were found either among men or women.
[a] Median (lower quartile–upper quartile). MMSE: Mini Mental State Examination; GDS: Geriatric Depression Scale; ADL: Activities of Daily Living.
[b] ADL comprised of eight variables: the capability of using toilet, washing up, taking a shower, taking a sauna, dressing-up and taking off one's clothes, getting in and out of bed, eating, and cutting toenails. Each variable consisted of five categories, and the range of the sum score of ADL was 8–40. A bigger figure indicates better performance.

Table 2
Anteroposterior and mediolateral velocities of sway and velocity moment in three standing balance tests at baseline and after a 12-month intervention in the intervention and control groups, by gender

	Intervention group		Control group		*p*-Value
	Baseline	Follow-up	Baseline	Follow-up	
Men					
Test 1	*n* = 35		*n* = 49		
Anteroposterior velocity (mm/s)	7.9 (5.8–9.5)	7.5 (5.9–8.5)	7.2 (6.4–9.7)	7.5 (6.3–8.8)	0.761
Mediolateral velocity (mm/s)	3.7 (2.9–4.4)	3.6 (2.6–5.0)	3.7 (2.8–5.2)	3.5 (2.8–4.8)	0.476
Velocity moment (mm^2/s)	10.0 (7.0–15.3)	8.9 (5.9–12.6)	8.9 (6.4–15.3)	9.1 (6.2–13.5)	0.713
Test 2	*n* = 35		*n* = 48		
Anteroposterior velocity (mm/s)	12.4 (9.5–15.6)	11.7 (9.1–17.4)	13.7 (9.8–17.9)	12.0 (10.1–18.0)	0.768
Mediolateral velocity (mm/s)	5.1 (3.9–7.0)	4.9 (3.4–5.9)	5.2 (3.7–7.4)	4.3 (3.3–7.1)	0.861
Velocity moment (mm^2/s)	20.1 (10.6–30.0)	15.6 (12.0–28.9)	20.8 (12.6–37.9)	16.5 (10.9–32.5)	0.489
Test 3	*n* = 34		*n* = 43		
Anteroposterior velocity (mm/s)	12.7 (9.9–15.3)	14.9 (11.6–15.9)	14.7 (11.1–17.3)	15.4 (11.2–19.9)	0.790
Mediolateral velocity (mm/s)	16.7 (15.1–24.2)	20.8 (16.5–25.7)	18.9 (16.6–22.5)	19.9 (17.2–25.2)	0.601
Velocity moment (mm^2/s)	51.7 (41.3–64.9)	65.8 (40.8–88.1)	59.5 (47.6–79.4)	67.4 (41.1–96.5)	0.340
Women					
Test 1	*n* = 211		*n* = 216		
Anteroposterior velocity (mm/s)	6.4 (5.3–8.3)	6.5 (5.3–8.1)	6.3 (5.3–8.0)	6.4 (5.2–8.1)	0.885
Mediolateral velocity (mm/s)	3.3 (2.8–4.6)	3.5 (2.8–4.5)	3.3 (2.6–4.2)	3.2 (2.6–4.1)	0.144
Velocity moment (mm^2/s)	8.0 (5.6–12.6)	7.5 (5.8–11.7)	7.4 (4.9–11.2)	7.0 (5.0–11.2)	0.919
Test 2	*n* = 206		*n* = 215		
Anteroposterior velocity (mm/s)	10.6 (8.3–14.6)	10.2 (7.9–13.7)	10.6 (7.8–13.3)	10.4 (7.8–13.9)	0.356
Mediolateral velocity (mm/s)	4.5 (3.6–6.2)[a]	4.5 (3.6–6.1)	4.1 (3.2–5.7)[a]	4.3 (3.2–5.5)	0.762
Velocity moment (mm^2/s)	15.1 (9.6–26.4)	14.1 (10.0–22.7)	13.7 (9.3–22.6)	13.6 (8.6–20.6)	0.328
Test 3	*n* = 193		*n* = 200		
Anteroposterior velocity (mm/s)	11.4 (9.4–14.2)	11.6 (9.2–14.4)	11.2 (9.0–14.1)	11.3 (9.2–14.7)	0.399
Mediolateral velocity (mm/s)	16.6 (13.6–20.5)	17.5 (14.5–20.4)	15.9 (12.9–19.4)	16.7 (13.6–20.7)	0.546
Velocity moment (mm^2/s)	46.0 (32.7–63.6)	46.4 (34.3–63.6)	43.2 (32.2–61.1)	45.6 (32.1–67.9)	**0.011**

Values are median (lower quartile–upper quartile). A smaller figure indicates better performance.
[a] Marginally significant ($p = 0.060$) differences between the groups at baseline.

3.2. Baseline characteristics

Among the 525 subjects who completed the study, there were no significant differences between the groups in the baseline characteristics among either men or women (Table 1).

3.3. Participation rates

The mean participation rate (the number of attended sessions divided by the number of sessions offered during the intervention) of the IG subjects were 64% among men and 63% among women in group exercises, 26% and 38% in lectures, and 22% and 29% in psychosocial groups, respectively. Men performed home exercises on an average of 2.5 (SD 2.2) and women 2.6 (2.0) times per week.

3.4. Changes during the intervention

In standing balance, there was a significant difference in the changes between the groups in the velocity moment of semi-tandem standing with eyes open among women (Table 2). This difference was in favor of IG. In the less demanding standing positions in tests 1 and 2 (normal standing, eyes open and closed),

Table 3
Performance times and distances of dynamic balance test and Berg Balance Scale (BBS) scores at baseline and after a 12-month intervention in the intervention and control groups, by gender

	Intervention group		Control group		*p*-Value
	Baseline	Follow-up	Baseline	Follow-up	
Men					
Dynamic test	*n* = 33		*n* = 47		
Time (s)	15.5 (13.4–19.1)	13.7 (12.1–15.7)	15.8 (13.4–19.2)	15.7 (11.9–19.0)	0.366
Distance (mm)	925.8 (830.6–1237.3)	1014.9 (825.5–1137.4)	1004.8 (820.7–1212.2)	1030.7 (856.4–1289.2)	0.473
	n = 37		*n* = 49		
BBS	53.0 (50.0–54.0)	54.0 (50.0–56.0)	53.0 (49.0–54.0)	53.0 (50.0–55.0)	0.247
Women					
Dynamic test	*n* = 195		*n* = 203		
Time (s)	15.7 (12.9–19.3)	13.4 (11.4–16.6)	15.6 (13.2–18.8)	14.4 (11.9–17.2)	0.264
Distance (mm)	1006.8 (854.8–1249.5)[a]	977.1 (842.8–1143.1)	968.1 (824.4–1165.1)[a]	971.0 (835.3–1187.7)	0.060
	n = 218		*n* = 219		
BBS	53.0 (50.0–55.0)	54.0 (51.0–56.0)	53.0 (49.0–55.0)	53.0 (50.0–55.0)	0.772

Values are median (lower quartile–upper quartile). A smaller figure indicates better performance in dynamic test and a bigger one in Berg Balance Scale (BBS) score.
[a] Marginally significant ($p = 0.079$) differences between the groups at baseline.

Table 4
Statistically significant or marginally significant differences in the changes between the groups in standing and dynamic balance among women aged 65–74 years and 75 years and older

	Intervention group		Control group		*p*-Value
	Baseline	Follow-up	Baseline	Follow-up	
Women <75 years					
Test 3 of standing balance	$n = 133$		$n = 145$		
Velocity moment (mm^2/s)	41.2 (30.8–58.9)	40.1 (32.6–56.8)	40.8 (31.2–52.6)	42.0 (30.7–56.2)	0.008
Women ≥75 years					
Dynamic test	$n = 61$		$n = 57$		
Time (s)	16.6 (14.4–21.6)[a]	14.9 (12.4–17.4)[a]	17.3 (14.2–22.0)[a]	15.6 (13.1–19.0)[a]	0.068
Distance (mm)	1085.3 (936.6–1406.3)	1046.4 (914.5–1195.4)	1040.4 (873.4–1336.9)	1062.3 (948.5–1364.5)	0.062

Values are median (lower quartile–upper quartile). A smaller figure indicates better performance. Median change in IG was −2.66 and in CG −0.90. No significant differences between the groups in baseline values either among women 65–74 years or among those 75 years and older.

no significant differences in the changes between the groups were found among women. Men showed no significant differences in the changes between IG and CG in any standing balance test.

The CG women performed marginally significantly better in the distance of dynamic balance test than the IG women at baseline (Table 3). The difference in the changes between the groups in the distance of dynamic balance test was significantly in favor of the IG women. No other significant differences in the changes between IG and CG were found either among men or women. Functional balance tested by BBS did not involve significant differences in the changes between the groups in men or women.

Subgroup analyses of the subjects aged 65–74 years and those of 75 years or over revealed significant or marginally significant differences in the changes between the groups among women, but not among men (limited data for subgroups in Table 4). In standing balance, there was a significant difference in the changes between IG and CG in the velocity moment of semi-tandem standing which improved in IG compared with CG among the women aged 65–74 years. Marginally significant differences in the changes between the groups emerged in the performance time and distance of the dynamic balance test among the women aged 75 years or over. These differences in the changes between the groups were also in favor of IG.

4. Discussion

The purpose was to determine whether a risk-based multifactorial fall prevention program improved the postural control of the community-dwelling aged with a history of falling. Most participants (84%) were women, which is consistent with the fact that more women than men are at risk of falling (Campbell et al., 1990). In standing balance, a positive effect was found only in the velocity moment of semi-tandem standing, which was the most demanding standing position used. This effect was found among all women and those aged 65–74 years. In the dynamic balance test, performance distance improved in IG but decreased in CG among all women and those aged 75 years or older. Greater improvement in IG than CG was found in the performance time of the dynamic test only among the women aged 75 years or older. No statistically significant differences in changes were observed among men.

The effects of prevention program on postural balance were good but not excellent. The absence of a greater effect on postural control could be due to several reasons. The participants aged 65 years and older and having experienced at least one fall during the previous 12 months may not have been frail enough to improve their balance due to the program. Forty-two percent of both men and women had experienced only one fall during the previous 12 months. A prospective study of a community population 70 years and older demonstrated that about 15% of falls result from an external event that would cause most people to fall (Campbell et al., 1989). People experiencing such falls are usually younger, more active and cognitively able, with no need for further action because of the fall (Campbell and Robertson, 2006). Only 11% of our participants scored 45 or less in BBS at baseline, which has been used as an indicator of an increased falling risk among the aged (Bogle-Thorbahn and Newton, 1996; Steadman et al., 2003). Another reason for the absence of a greater effect may be that the exercises were not intensive enough. The group exercises were performed twice a month. The participation rates in the exercise sessions were 64% among men and 63% among women. The subjects were also advised to perform physical exercises similar to those performed in groups three times a week at home, and 32% of men and 38% of women did so. Women participated in lectures and psychosocial groups more often than men, hence showing better compliance than men. Participation in fall prevention trials is low and variable (Campbell and Robertson, 2006). Acceptance has been especially low with interventions some people find unacceptable, such as psychotropic drug withdrawal (Tinetti et al., 1994; Campbell et al., 1999). However, participation in actual programs is assumed to be greater (Campbell and Robertson, 2006). Thirdly, drop-out analysis revealed that the women who failed to complete the study were older and had poorer physical, cognitive, and psychological functional abilities than those completing. Hence, those most likely to benefit from the intervention (Tinetti et al., 1996; Campbell et al., 1997; Robertson et al., 2002) were not reached.

In the study, non-parametric statistical tests were used due to the distributions of the outcome variables were extremely skewed. In addition, there was no need to use baseline variables as covariates because no differences were detected between the groups in baseline characteristics.

Our results are in line with an earlier randomized controlled multifactorial fall prevention study implemented among 250 fall-prone community-dwelling aged persons, where the number of subjects with balance impairment diminished during the median follow-up period of 4.5 months (Tinetti et al., 1994). Another randomized controlled study also showed that significant improvements in functional balance can be gained by a 10-week home-based multifactorial fall prevention among the community-dwelling aged without a specified risk factor for falling. The sample size of the study was only 37, and the follow-up period was short (10 weeks) (Yates and Dunnagan, 2001). Our intervention was long (12 months), and the effects on falls, injurious falls and all-cause mortality will be followed up for 5 years. With 591 subjects recruited, this is also by far the largest risk-based multifactorial fall prevention trial in Finland.

The measurements of postural balance used in our study have been established as reliable. The test–retest reliability of standing balance tests in normal standing with eyes open and closed (Hofmann, 1998; Sihvonen and Era, 1999) and in the performance time and distance of the dynamic balance test have been found to be good (Sihvonen et al., 2004). The reliability and validity of the Berg Balance Scale has been tested among elderly persons (Berg et al., 1995), and it is one of the most widely used functional balance tests.

The multifactorial nature of the intervention makes it difficult to conclude which aspects of the program facilitated the positive effects. It could be assumed that the most effective components for balance improvements were the group exercise sessions and home exercises. Day et al. (2002) examined the benefits of each component of their multifactorial fall prevention intervention and found the exercise program most effective in preventing falls and improving balance. Home hazard management and vision screening and referral were not markedly effective when used alone but added value when combined with an exercise program. The reduction in falls was associated with improved balance.

4.1. Conclusions

Twelve-month risk-based multifactorial fall prevention program had favorable effects on the postural control of women only in the most demanding standing balance test used. The improvements of performance distance and time in dynamic balance test in women aged 75 years and older in our study may demonstrate more confident postural control close to the limits of stability. Whether these improvements are associated with a reduction of falls among women will be analyzed later.

Acknowledgements

The authors wish to thank the following organizations for their financial support for the study: Southwestern Finland Hospital District, Satakunta Hospital District, The Päivikki and Sakari Sohlberg Foundation and the Academy of Finland.

References

Barnett, A., Smith, B., Lord, S., Williams, M., Baumand, A., 2003. Community-based group exercise improves balance and reduces falls in at-risk older people: a randomised controlled trial. Age Ageing 32, 407–414.

Berg, K., Wood-Dauphinée, S., Williams, J., Gayton, D., 1989. Measuring balance in the elderly: preliminary development of an instrument. Physiother. Can. 41, 304–311.

Berg, K., Wood-Dauphiné, e, S., Williams, J., 1995. The balance scale: reliability assessment with elderly residents and patients with an acute stroke. Scand. J. Rehabil. Med. 27, 27–36.

Bogle-Thorbahn, L.D., Newton, R.A., 1996. Use of the Berg balance test to predict falls in elderly persons. Phys. Ther. 76, 576–585.

Borg, G., 1998. Borg's Perceived Exertion and Pain Scales. Human Kinetics, Champaign (IL).

Brouwer, B.J., Walker, C., Rydahl, S.J., Culham, E.G., 2003. Reducing fear of falling in seniors through education and activity programs: a randomised trial. J. Am. Geriatr. Soc. 51, 829–834.

Campbell, A.J., Robertson, M.C., 2006. Implementation of multifactorial interventions for fall and fracture prevention. Age Ageing 35, S60–S64.

Campbell, A.J., Borrie, M.J., Spears, G.F., 1989. Risk factors for falls in a community-based prospective study of people 70 years and older. J. Gerontol. 44, M112–M117.

Campbell, A.J., Spears, G.F., Borrie, M.J., 1990. Examination by logistic regression of the variables which increase the relative risk of elderly women falling compared to elderly men. J. Clin. Epidemiol. 43, 1415–1420.

Campbell, A.J., Robertson, M.C., Gardner, M.M., Norton, R.N., Tilyard, M.W., Buchner, D.M., 1997. Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. Br. Med. J. 314, 1065–1069.

Campbell, A.J., Robertson, M.C., Gardner, M.M., Norton, N.R., Buchner, D.M., 1999. Psychotropic medication withdrawal and a home-based exercise program to prevent falls: a randomized, controlled trial. J. Am. Geriatr. Soc. 47, 850–853.

Day, L., Fildes, B., Gordon, I., Fitzharris, M., Flamer, H., Lord, S., 2002. Randomised factorial trial of falls prevention among older people living in their own homes. Br. Med. J. 325, 128–133.

Era, P., Schroll, M., Ytting, H., Gause-Nilsson, I., Heikkinen, E., Steen, P., 1996. Postural balance and its sensory-motor correlates in 75-year-old men and women: a cross-national comparative study. J. Gerontol. A: Biol. Sci. Med. Sci. 51, M53–M63.

Gillespie, L.D., Gillespie, W.J., Robertson, M.C., Lamb, S.E., Cumming, R.G., Rowe, B.H., 2003. Interventions for preventing falls in elderly people (Cochrane Review). In: The Cochrane Library, Issue 3, Update Software, Oxford.

Hofmann, C., 1998. The Implementation of Normative Data in a Force Platform based Postural Balance Measurement System. Diplomarbeit Westsächsische Hochschule Zwickau (FH), Fachbereich Physikalische Technik/Informatik.

Latham, N.K., Anderson, C.S., Lee, A., Bennett, D.A., Moseley, A., Cameron, I.D., 2003. A randomized controlled trial of quadriceps resistance exercise and vitamin D in frail older people: the frailty interventions trial in elderly subjects (FITNESS). J. Am. Geriatr. Soc. 51, 291–299.

Lord, S.R., Castell, S., Corcoran, J., Dayhew, J., Matters, B., Sahn, A., Williams, P., 2003. The effect of group exercise on physical functioning and falls in frail older people living in retirement villages: a randomized, controlled trial. J. Am. Geriatr. Soc. 51, 1685–1692.

Nitz, J.C., Low Choy, N., 2004. The efficacy of a specific balance-strategy training programme for preventing falls among older people: a pilot randomised controlled trial. Age Ageing 33, 52–58.

Robertson, M.C., Campbell, A.J., Gardner, M.M., Devlin, N., 2002. Preventing injuries in older people by preventing falls: a meta-analysis of individual-level data. J. Am. Geriatr. Soc. 50, 905–911.

Rubenstein, L.Z., 2006. Falls in older people: epidemiology, risk factors and strategies for prevention. Age Ageing 35, S37–S41.

Rubenstein, L.Z., Josephson, K.R., Trueblood, P.R., Loy, S., Harker, J.O., Pietruszka, F.M., Robbins, A.S., 2000. Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. J. Gerontol. A 55, M317–M321.

Sihvonen, S., Era, P., 1999. Test–retest reliability of easy and more demanding balance tests in young, middle-aged, and elderly participants (congress abstract). J. Aging. Phys. Act. 7, 312.

Sihvonen, S., Sipilä, S., Era, P., 2004. Changes in postural balance in frail elderly women during a 4-week visual feedback training: a randomized controlled trial. Gerontology 50, 87–95.

Sjösten, N., Salonoja, M., Piirtola, M., Vahlberg, T., Isoaho, R., Hyttinen, H., Aarnio, P., Kivelä, S.-L., 2007. A risk-based multifactorial fall prevention program in the home-dwelling aged: a randomized controlled trial. Public Health 121, 308–318.

Song, R., Lee, E.O., Lam, P., Bae, S.C., 2003. Effects of tai chi exercise on pain, balance, muscle strength, and perceived difficulties in physical functioning in older women with osteoarthritis: a randomized clinical trial. J. Rheumatol. 30, 2039–2044.

Steadman, J., Donaldson, N., Kalra, L., 2003. A randomized controlled trial of an enhanced balance training program to improve mobility and reduce falls in elderly patients. J. Am. Geriatr. Soc. 51, 847–852.

Tinetti, M.E., Baker, D.I., McAvay, G., Claus, E.B., Garrett, P., Gottschalk, M., Koch, M.L., Trainor, K., Horwitz, R.I., 1994. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. N. Engl. J. Med. 331, 821–827.

Tinetti, M.E., McAvay, G., Claus, E., 1996. Does multiple risk factor reduction explain the reduction in fall rate in the Yale FICSIT trial? Am. J. Epidemiol. 144, 389–399.

Yates, S.M., Dunnagan, T.A., 2001. Evaluating the effectiveness of a home-based fall risk reduction program for rural community-dwelling older adults. J. Gerontol. A 56, M226–M230.