Clinical Rehabilitation 2001; **15**: 624–636

Effect of a physical therapeutic intervention for balance problems in the elderly: a single-blind, randomized, controlled multicentre trial

Bernard Wolf Department of Physical Therapy, Stichting Zorgcentrum Texel, The Netherlands, **Hilde Feys, Willy De Weerdt** Department of Rehabilitation Science, Faculty of Physical Education and Physiotherapy, Katholieke Universiteit Leuven, Leuven, Belgium, **Jaap van der Meer** Department of Biostatistics, Netherlands Institute for Sea Research (NIOZ), **Margo Noom** Department of Physical Therapy, Stichting Zorgcentrum Texel and **Geert Aufdemkampe** Department of Physical Therapy, Polytechnic of Utrecht, The Netherlands

Received 4th September 2000; returned for revisions 23rd October 2000; revised manuscript accepted 17th December 2000.

Objective: To establish the effect of a short, individualized exercise programme on balance dysfunction in the elderly.
Design: A single-blind, randomized, controlled, multicentre trial.
Setting: Physical and recreational therapy departments from two rehabilitation centres.
Participants: Ninety-four subjects of ≥75 years with functional balance problems living independently or in a residential care facility. Seventy-seven subjects completed the intervention period and four-week follow-up. At a one-year follow-up 49 subjects were evaluated on balance functioning.
Interventions: Twelve sessions of an individualized balance training programme (experimental group) or 12 sessions of an individualized extra attention programme (control group) given in 4–6 weeks.
Main outcome measures: Berg Balance Scale and the Dynamic Gait Index to establish balance functioning, a visual analogue scale to establish fear of falling in daily life and the Hospital Anxiety Depression Scale to verify feelings of anxiety and depression.
Results: Subjects in the experimental group improved significantly more on the Berg Balance Scale and the Dynamic Gait Index than those in the control group ($p \leq 0.001$, $p \leq 0.001$, respectively). However the effect disappeared at a one-year follow-up on the Berg Balance Scale. No prognostic factors could be identified to determine who would benefit most from the individualized exercise programme. Results on the other response variables revealed no effect of the intervention.
Conclusion: A short individualized exercise programme can improve functional balance in people aged 75 years and older. This improvement was maintained at least for one month but had worn off by one year.

Address for correspondence: Bernard Wolf, Department of Physical Therapy, Stichting Zorgcentrum Texel, PO Box 107, 1790 AC Den Burg (Texel), The Netherlands.

0269–2155(01)CR456OA

Introduction

In the Netherlands each year 20 000 individuals over the age of 75 are admitted to hospital due to an accident at home. Most cases (84%) are due to falling incidents merely while walking.[1] Approximately one-third of the older people who never had a fall and about 50% of those who have experienced a fall affirm that fear of falling restricts them in their daily activities.[2,3] In the last decade much research has been performed to identify risk factors related to fall incidents.[4-6] Both extrinsic and intrinsic factors play a role.[7-10] The apparent relationship between balance control, age and risk of falling stimulated studies of the relation between age and balance,[11] the development of standardized procedures for measuring balance[12-14] and studies to predict the risk of falling for older people.[15,16] Other investigators compared several psychological indicators of balance confidence in relation to physical performance.[17]

Various studies have examined the effect of specific exercises on balance in older people with conflicting results.[18-21]

Two studies[22,23] found that an individualized exercise programme improved balance and functional abilities. However, the studies suffered from methodological shortcomings. The first study had small sample size and no control group.[22] The other study did not assign individuals randomly to treatments and there was no blind assessment.[23]

The present study compared the effects of an individualized exercise programme based on the system approach[24] in comparison to the effects of extra attention for individuals over 75 years of age with impaired balance. The study addressed the following questions: (1) Does an individualized exercise programme affect balance function in people over 75 years of age? (2) Does an individualized exercise programme affect the fear of falling and, more generally, feelings of anxiety and depression? and (3) Which individuals benefited more from the physical therapeutic intervention?

Methods

Study design

A repeated-measures experimental design with two treatments (experimental and control) was chosen. The experimental treatment focused on an improvement of the balance, whereas all individuals within the control group received extra attention.

Based on previous estimates of within-treatment variability,[22] we estimated that a sample size of 48 individuals in each group would suffice to detect a difference between the two treatments of four points in the Berg Balance Scale (BBS),[12] the main response variable, with a statistical power of 80%, given a type I error rate of 5%. A four-point difference in BBS either means a slight improvement in four items (out of 14) or a major improvement (from no ability to fully unsupported acting) in one item. To reduce accidental variability in initial scores between the two groups, individuals were first stratified into two strata before random assignment into the two treatments. The two strata consisted of individuals with a BBS score from 0 to 40 and 41–52, respectively. It has been shown that individuals from the first stratum have a higher risk of falling.[15]

For both strata the subjects were randomly assigned to the two treatments using sealed envelopes which were selected by a blindfolded person.

The six physical therapists and six recreational therapists, all experienced in geriatric rehabilitation, were assigned haphazardly to either subjects of the experimental group or subjects of the control group.

Subject selection

Patients were recruited from three local residential care facilities, via family physicians, district nurses and by a call for participation in the local newspaper. Subjects had to meet the following criteria: (1) over 75 years of age; (2) minimal loss of visual acuity; (3) not recovering from acute illness; (4) no physical therapy during the previous month; (5) a minimum score of 17 on the Mini-Mental State Examination; (6) a BBS score of no more than 52 out of a maximum of 56 points possible and (7) an impaired balance during functional activities.

To be sure that the subjects' impaired balance functioning matched the criteria for participation in this study, all subjects were observed and tested by physical therapists who were unaware of the obtained BBS scores. Based on the physical therapists' personal judgement on subjects' performance on the Dynamic Gait Index,[16,24] the ability to perform transfers, to walk over various surfaces and slopes and activities of daily living (ADL) it was decided whether subjects were finally included. The selecting physical therapist was not allowed to administer the physical therapeutic intervention. Figure 1 shows the subjects' progress through the trial.

All subjects signed informed consent to participate in the study. The family physician was asked for a 'statement of no objection' and information on health status.

Treatment

One of the premises of this study was that each subject has his or her own balance problems, which can be the result of a variety of underlying factors. After careful clinical examination the physical therapist developed for each subject an individualized balance training programme in accordance with the system approach. This approach argues that it is critical to recognize that movement emerges from an interaction between the individual, the task, and the environment in which the task is carried out.[24] The primary goal was to obtain an optimal balance during performance of ADLs and when walking. The term 'optimal' refers to both the development of task-specific strategies concerning anticipatory and ongoing postural adjustments and strategies to compensate for deficiencies in the ability to respond to external stimuli. The therapist endeavoured to improve (1) mobility; (2) muscular strength; (3) stability; (4) co-ordination; (5) endurance; (6) ability to respond to external stimuli and/or (7) self-confidence. Exercises in sitting, standing and walking were performed to improve balance. Balance was also trained during ADL activities in a variety of situations (home, street, shops, children's playground). Physical therapists were asked to describe treatment goals for each subject. For each session exercises were registered.

For each subject 12 sessions (twice or three times a week during 4–6 weeks) were held. Each session lasted 30 minutes and took place at the subject's home or at a physical therapy department.

For the control group individual-oriented activities were chosen in accordance with the subject's own abilities, interests and preferences. The following activities were offered: (1) handicraft, e.g. needlework, woodworking, painting, writing; (2) music, e.g. singing, playing records, playing instruments; (3) media, e.g. reading books, magazines and newspapers, watching TV or video, computer course; (4) board games; (5) discussion groups; (6) memory training; and (7) car tours in the surroundings. Frequency and duration of the sessions were similar as for the physical therapy group. All activities were registered.

Evaluation

Measurements were taken (1) before the therapy started, (2) after the therapy and (3) the fourth week after the end of therapy. For each subject evaluation occurred at the same place and time of the day. Subjects who completed the first three evaluations and received no physical therapy during the year thereafter were also evaluated on the main outcome measure (BBS) one year after finishing the treatment period. The one-year follow-up took place at the subject's home.

Age, sex, frequency of falls during the last six months, presence of orthostatic hypotension and number of co-morbidities were documented at entry to the study. Balance was evaluated with the Berg Balance Scale.[12,13,25] This rates performance on 14 different activities in an increasing order of difficulty from sitting unsupported to standing on one leg. Each task is measured on a five-point ordinal scale ranging from 0 (unable) to 4 (independent) (see Appendix 1). The scale has proven to be sensitive, reliable and valid.[12,26–28]

The Dynamic Gait Index[16,23,24] was used to evaluate subjects' balance performance on changing task demands during walking. This test contains eight items and each of them is measured on a four-point ordinal scale. The scale has

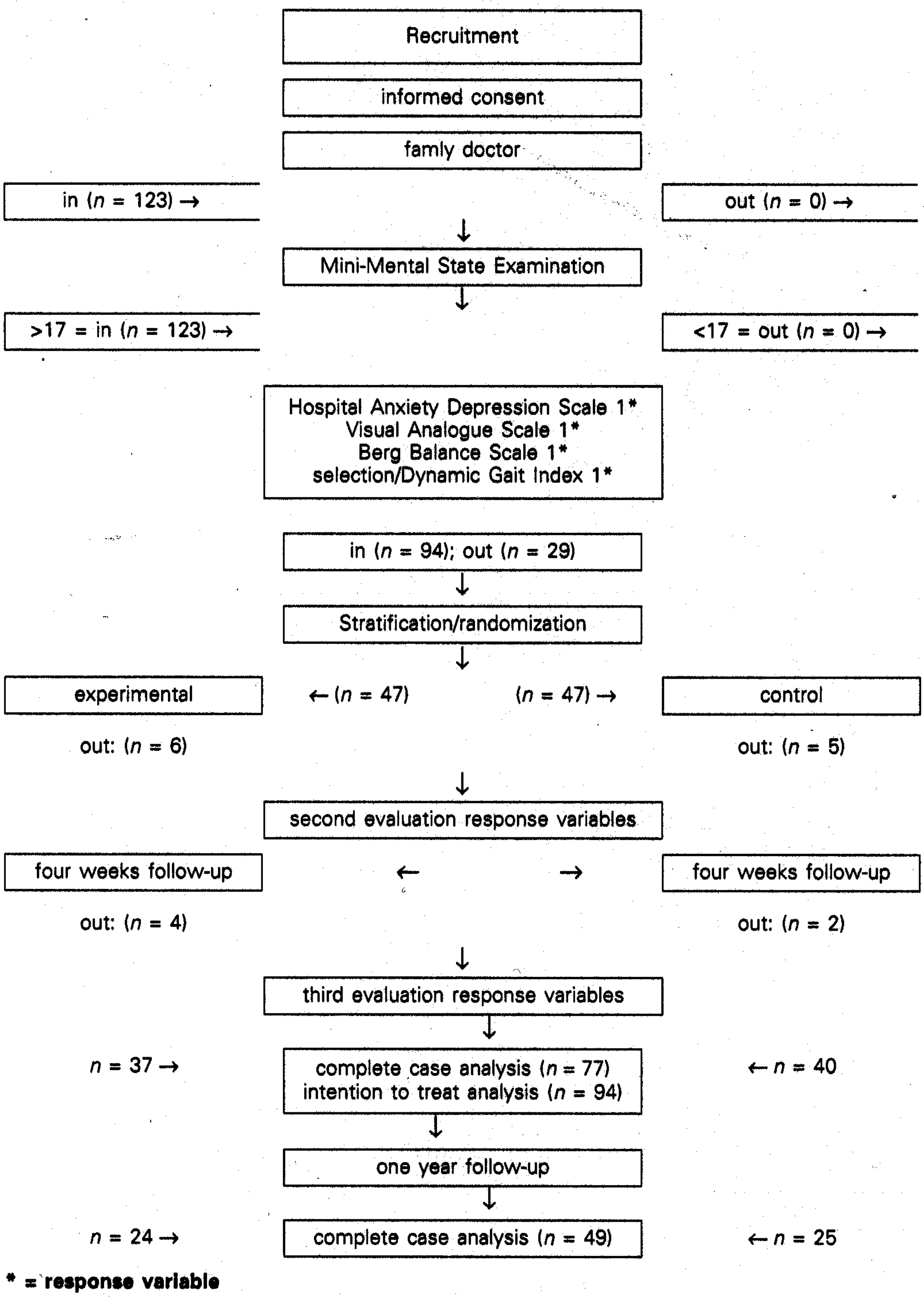

Figure 1 Flow chart describing subjects' progress through the trial.

proven to be reliable[24] (see Appendix 2).

Feelings of anxiety and depression experienced before and after the interventions were estimated by the Hospital Anxiety and Depression Scale (HADS).[29,30] Anxiety and depression each range from 0 to 21. A score of 0–7 is considered as normal, 8–10 is borderline and a score between 11 and 21 means cause for concern. As an indication of fear of falling in daily life a visual analogue scale (VAS) was used. Subjects were asked to express their overall feelings of fear of falling by drawing a mark on a vertical line of exactly 100 mm connecting the two statements: 'no fear of falling' (below) and 'very afraid of falling' (above). The score was the number of millimetres between 'no fear of falling' and the subject's mark.

A detailed clinical examination was performed to develop the individual treatment programme. This included the Romberg test, range of motion of the lower extremities and cervical spine, muscle strength and tone (Ashworth Scale), reflexes, sensation, vestibular functioning and postural reflexes.

Physical therapists from rehabilitation centres in Texel and Den Helder (the Netherlands) practised this examination jointly and each therapist was provided with a detailed instruction booklet.

For the two balance variables (BBS and DGI) intra- and inter-observer repeatability were verified. The intra-observer and inter-observer intraclass correlation coefficients (ICCs), using a random ANOVA model, were 0.98 and 0.98 for BBS, and 0.98 and 0.99 for DGI. All subjects were scored on the Berg Balance Scale by a therapist who was blinded for the treatment given. All other response variables were evaluated by therapists who were not involved in the treatments, but due to the logistics of scheduling treatments there was no guarantee they were blinded to the facts. The therapists who carried out the interventions were blinded for the scores obtained on both the Berg Balance Scale and Dynamic Gait Index.

Statistical analysis

All response variables were checked for normality by visual inspection of the normal probability plots. Non-normal data were transformed by an appropriate power transformation: BBS and DGI were squared and additionally multiplied by a constant such that they were expressed on a scale ranging from 0 to 10. The HADS-anxiety was root transformed and the HADS-depression was log-transformed. Sample size characteristics of subjects in the experimental and control group were compared by means of chi-square tests or unpaired t-tests. The response variables of the two groups were compared before treatment using unpaired tests and Wilcoxon tests.

The hypothesis of no difference between the two treatments interventions was tested by a multivariate analysis of variance (MANOVA). Since only two interventions are involved, this test is equivalent to Hotelling's T^2-test, which is the multivariate analogue of the two-sample Student's t-test. Two sample t-tests were used to test whether the difference between the second and first observation and the difference between the third and the second observation differed among the two interventions[31] (see Appendix 3).

Additionally, several prognostic factors were incorporated in the multivariate linear model (i.e. an extension of the MANOVA model) to identify groups of patients who did benefit most from the therapy. Only individuals who completed the whole study were included (complete case analysis). To handle missing responses, an intention to treat analysis was carried out on balance variables using the last observed response (carry forward).

Results

Subjects

Ninety-four persons who met the selection criteria were included. During the first period 11 subjects (experimental group $n = 6$; control group: $n = 5$) discontinued the trial. Between the second and third evaluation another six people fell out (experimental group $n = 4$; control group $n = 2$). Reasons for discontinuing were: death ($n = 1$), admission to a hospital or nursing home ($n = 6$), flu ($n = 4$), private reasons ($n = 5$) and moved to another town ($n = 1$).

Approximately 25% of treatments given to both the experimental group and control group occurred at the subject's home.

Deviation from random allocation due to false inclusion or noncompliance did not occur.

The sample characteristics of the 77 subjects who completed both the evaluations on the Berg Balance Scale and the Dynamic Gait Index are presented in Table 1. There was an average of 2.7 diagnoses listed per subject. The most frequently occurring diagnoses were categorized as cardiorespiratory ($n = 65$), musculoskeletal ($n = 62$) and neurological ($n = 21$).

Twenty-eight subjects (experimental group $n = 13$, control group $n = 15$) could not be tested on the Berg Balance Scale at the one-year follow-up. Twelve people died, two moved to another town, two because of private reasons, two due to admission to a hospital and one person suffered from the flu. Another nine subjects were excluded because they received physical therapy after the third evaluation.

Effect of the intervention

Details of the response variables for each group, before and immediately after the intervention and at the four-week follow-up are shown in Table 2. At the onset of the trial groups were comparable for all response variables.

The functional balance variables BBS and DGI showed a different pattern of evolution over time between the two interventions (Figure 2a, b). The multivariate analysis of variance of the complete case analysis revealed a significant difference between the two interventions in the two transformed functional balance variables BBS (Hotellings' trace = 0.347, $F(3,73) = 8.4$, $p < 0.001$) and DGI (Hotellings' trace = 0.572, $F(3,73) = 13.93$, $p < 0.001$). The experimental group showed a greater improvement in test scores between the first and second evaluation when compared with the control group. The *t*-tests confirmed a significant change in the treat-

Table 1 Sample characteristics of subjects in the control and experimental group

	Control group ($n = 40$)	Experimental group ($n = 37$)	*p*-value	Significance
Age				
Mean	83,6	84,5	0.49(*t*)	ns
SD	5,1	6,1		
Range	75/94	75/97		
Sex				
Male	14	7	0.11χ	ns
Female	26	30		
MMSE				
Mean	22,2	23,1	0.08(*t*)	ns
SD	2,5	1,7		
Range	17/25	18/25		
Living				
Independently	26	23	0.79χ	ns
Care centre	14	14		
Marital status				
Married	5	9	0.20χ	ns
Single	35	28		
Walking aids				
None	7	5	0.45χ	ns
Walker/cane	32	32		
Wheelchair	1	0		
Freqency of falls in last 6 months				
None	20	18	0.70χ	ns
1x	10	7		
>1x	10	12		

t, Student's *t*-test; χ, chi-square test; MMSE, Mini-Mental State Examination; ns, not significant.

Table 2 Results of the response variables before, immediately after and four weeks post-intervention in the two treatment groups (control group $n = 40$, experimental group $n = 37$)

	Before intervention		After intervention		Follow-up	
Response variables	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group
BBS						
Mean	36.8	37.3	38	42.5	37.9	41.5
SD	13.16	12,11	12.75	11.11	13.87	10.93
Range	4/52	11/51	4/53	13/55	4/54	12/55
DGI						
Mean	13.3	14.3	13.5	18.1	13.4	16.9
SD	6.45	4.92	6.45	5.44	7.1	6.16
Range	0/21	0/23	0/22	0/24	0/22	0/24
VAS						
Mean	40.2	38.1	44.7	38.6	45.8	42.1
SD	32.52	31.03	29.89	29.68	28.72	25.51
Range	0/96	0/99	0/93	0/98	0/98	0/88
HADS-a						
Mean	4.8	5.1	4.3	4.3	4.9	4.1
SD	3.91	4.22	3.41	3.85	3.83	3.6
Range	0/17	0/12	0/13	0/14	0/15	0/12
HADS-d						
Mean	6.4	4.9	5.6	4.8	5.5	5.3
SD	4.69	3.5	4.01	3.85	4.62	3.67
Range	2/20	0/13	0/18	0/14	0/17	0/13

BBS, Berg Balance Scale; DGI, Dynamic Gait Index; VAS, visual analogue scale; HADS-a, Hospital Anxiety and Depression Scale – anxiety; HADS-d, Hospital Anxiety and Depression Scale – depression.

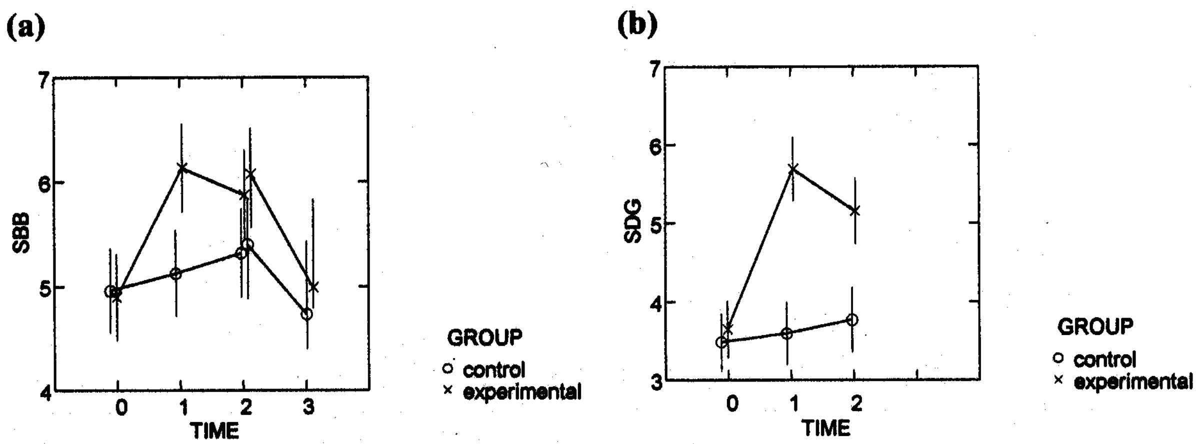

Figure 2 (a) Means and standard errors ($n = 77$) of the squared scores on the Berg Balance Scale (SBB) for the control (O) and experimental (X) groups before (0), immediately after (1), at a follow-up at 4 weeks after the intervention period (2) and (3) at one year follow-up ($n = 49$). (b) Means and standard errors ($n = 77$) of the squared scores on the Dynamic Gait Index (SDG) for the control (O) and experimental (X) groups before (0), immediately after (1) and at a follow-up at four weeks after the intervention period (2)

ment period (Table 3). The mean difference for Berg Balance Scale scores after the intervention was +1.2 points for the control group and +5.2 points for the experimental group. The mean difference for DGI scores after the intervention was +0.2 points and +3.8 points, respectively. This profit could not be fully retained in the follow-up period, though subjects in the experimental group ended up with higher scores compared to the control group.

The change in the second period was not significantly different between the two interventions on the Berg Balance Scale. However, inspection of the residuals pointed to two outlying observations, who had a Mahalanobis distance of 4.2 and 5.7. Exclusion of these outliers resulted in a significantly different change in the second period (Table 3), in which the control group still increased in BBS, but the experimental group showed a decline in BBS (Figure 2a). The test results for the intention to treat analysis only marginally differed from the complete case analysis. The largest difference in *p*-values concerned the *t*-test of the change in DGI during the second period with $p = 0.037$ instead of $p = 0.032$.

Table 4 shows the distribution of improvement of the scores on the Berg Balance Scale and Dynamic Gait Index between the first and second evaluation in the control and experimental groups in more detail. Fifty-nine per cent of subjects in the experimental group improved four points or more on the BBS compared with 7.5% in the control group. On the DGI, 65% in the experimental group showed an improvement of more than three points in comparison with 10% of control subjects.

The mean BBS score after one year (Figure 2a) was 36.12 (±13.51) in the control group ($n = 25$) and 36.79 (± 14.86) in the experimental group ($n = 24$). The MANOVA $F(1,46) = 1.17, p = 0.29$) showed no significant change over time between the two groups ($n = 49$).

The MANOVA revealed no significant difference between groups for the other outcome vari-

Table 3 Two-sample *t*-test of the hypothesis that the change in squared Berg Balance Scale and in squared Dynamic Gait Index, in the first and second period respectively does not differ between the control and experimental group. Residual degrees of freedom equalled 73

Variable	Period	Effect	95% CI	*p*-value
SBB	1	−1.074	−1.438,−0.710	<0.001
SBB	2	0.451	0.129, 0.773	0.007
SDG	1	−1.993	−2.550,−1.315	<0.001
SDG	2	0.708	0.123, 1.292	0.018

SBB, Squared Berg Balance Scale; SDG, Squared Dynamic Gait Index; Effect, mean difference between the two groups in the average change; 95% CI, 95% confidence interval of the effect.

Table 4 Distribution of points of improvement on the Berg Balance Scale (BBS) and the Dynamic Gait Index (DGI) between the first and second evaluation in the control and experimental group

Control group (*n* = 40)			Experimental group (*n* = 37)		
BBS	*n*	%	BBS	*n*	%
≤0	17	42.5	≤0	5	13.5
1–3	20	50.0	1–3	10	27.0
4–7	2	5.0	4–7	15	40.5
≥8	1	2.5	≥8	7	18.9
DGI	*n*	%	DGI	*n*	%
≤0	27	67.5	≤0	5	10.8
1–2	9	22.5	1–2	10	27.0
3–5	3	7.5	3–5	13	38.1
≥6	1	2.5	≥6	10	27.0

ables (HADS-anxiety: Hotellings' trace = 0.024, $F(3,66) = 0.53$, $p > 0.05$; VAS: Hotellings' trace = 0.028, $F(3,65) = 0.61$, $p > 0.05$) with exception of the HADS-depression scores (HADS-depression: Hotellings' trace = 0.142, $F(3,66) = 3.12$, $p = 0.03$). However, the *t*-test could not detect a significant change in the first ($p = 0.39$) and second ($p = 0.13$) period regarding the results on the HADs-depression variable. At the start of the intervention there was an almost significant difference ($p = 0.059$) on the HADS-depression in favour of the experimental group (Table 2). This most likely explains why the MANOVA revealed a significant difference for feelings of depression in the control group which were not confirmed in the a posteriori test.

To identify groups of patients that benefited most from the therapeutic intervention on the Berg Balance Scale, the effects of age, Mini-Mental State Examination scores, frequency of falls, range of motion and muscle strength of the lower extremities, range of motion of the cervical spine, orthostatic hypotension, vestibular deficits, coordination of lower and upper extremities, postural reflexes, the Romberg test, muscle tone, deep sensation and the number of co-morbidities were added to the multivariate model. The only prognostic factor that significantly contributed to the model was the factor muscle strength. However, inspection of the data revealed that this effect was solely due to two individuals who had extreme low muscle strength at the onset of the trial. After exclusion of these two individuals no observable effect was left.

Discussion

The observed changes in the Berg Balance scores and the Dynamic Gait Index revealed that a short and individualized physical therapy training programme based on the system approach can significantly improve balance function. The mean difference in improvement after the intervention period on the Berg Balance Scale was four points. This improvement was considered clinically relevant at the outset of the study and cannot be attributed to a few outlying results (Table 4). Almost 60% of the subjects in the experimental group showed an improvement of more than four points on the Berg Balance Scale and 65% improved more than three points on the Dynamic Gait Index. For the control group these scores were 7.5% and 10%, respectively. In contrast the number of subjects making small improvements on the BBS and the DGI is much higher in the control group than in the experimental group.

Clinical messages

- Declining balance function is a major problem in the elderly. Various studies examined the effect of physical therapy on balance function in older people. They have suggested that exercise programmes may be effective but until now evidence from randomized controlled trials has been lacking.
- This randomized study shows that balance function can be improved in people over 75 years of age with reasonable good cognitive function. Yet, the results suggest that maintaining balance function may require an ongoing process of training.

It was encouraging to notice that balance function can be improved in people over 75 years of age by an intensive short individualized exercise programme. Mulder *et al.*[34] investigated the sensorimotor adaptability in the elderly and noted that the older subjects showed significantly more problems than younger people performing concurrent tasks. The Dynamic Gait Index implements this dual-tasking aspect and therefore appeared to be a useful co-indicator of balance functioning in this project.

Though the balance scores decreased again, the improvement achieved on balance function did not immediately disappear when the therapy ended.

The mean improvement on the Berg Balance Scale as a result of the intervention correspond with the results reported by Harada *et al.*[22] and Shumway-Cook *et al.*[23] Both studies used an individualized exercise programme in order to improve functional balance performance. Willems and Vandervoort[32] found similar results in a study to investigate the extent to which balance function is a contributing factor to gait velocity in geriatric rehabilitation inpatients. Hu and Woollacott[21] reported an improved balance as a result of exercises aimed at optimizing the interaction of the visual, vestibular and the somatosensory systems for people aged 65–90. The results of the four aforementioned and this study show that deterioration of balance function can be reversed with training. This is in agreement with the results of other researchers as well. Westhoff *et al.*[20] claimed that a muscle strength training programme for people with a decreased functioning of the M. quadriceps femoris significantly increased the performance in the 'timed up and go' test and a balance test for people over 65 years of age. These results were not confirmed by Topp *et al.*[18] however, who could not establish a significant effect of dynamical resistance exercises (in comparison to a control group) on walking speed and balance. Judge *et al.*[19] could not demonstrate a significant effect of a muscular strength training programme for the lower extremities (in comparison to a balance training programme) on walking speed and chair rise time either. However, the use of different measurements and training programmes and the lack of uniformity on defining balance function does not allow a straightforward comparison of the results of these studies.

Fear of falling is a well-known phenomenon amongst older people and has been investigated by several researchers.[2,3] In a prospective study of falls over a two-year period Vellas *et al.*[3] observed that subjects who were afraid of falling showed deterioration of balance, gait and cognitive function resulting in a decrease in mobility level. Howland *et al.*[2] found similar results in a study on covariates of fear of falling in relation to activity curtailment. Tennstedt *et al.*[33] reported that a group intervention to reduce fear of falling among older adults had an immediate beneficial effect that diminished over time. To the best of our knowledge no studies have been undertaken to investigate the effect of an individual tailored physical therapy programme on fear of falling.

The results of this study showed that after the intervention no significant difference occurred between both groups regarding fear of falling in daily life (VAS). A 4–6 week intervention might be too short to establish an effect. Yet, fear of falling might be a natural way of preventing falls and should be respected as such.

Except for extreme poor muscular strength observed in two subjects at the onset of this study, no prognostic factors could be identified to determine who will most likely benefit from a physical therapeutic intervention based on the system approach. These findings confirm the present understanding on declining balance function in very old people. Balance performance is the result of a multifactorial system interaction within the body in relation to the environment. The measurable difference from normal is not a measure of the defect itself, it is the effect of what remains after the system has compensated for the inadequacy.[5,6,35]

The physical therapeutic intervention presented in this study appeared to be successful and can be applied to people at high age with poor balance. Yet, it should be noticed that participating subjects had reasonable good cognition. Therefore results might have been different if subjects with poor cognitive function were included. Another limitation of this study was that physical therapists evaluating subjects' performance on the Dynamic Gait Index were not blinded for the treatment given. This was due to the fact that therapists occasionally treated their patients in the same room at the same time. However, to minimize the possibility of evaluator bias, evaluators had no access to pretest scores.

Finally, the results of the one-year follow-up on the Berg Balance Scale seem to indicate that an ongoing balance training programme is required in order to maintain balance function. According to the 'systems approach', future studies should focus on the way family and health care workers best contribute in an ongoing balance training programme in order to get optimal results for all involved.

Acknowledgements

This study was supported by the C.E. Gollardsstichting, Univé Zorgverzekeraar, the City council of Texel, Taxi 312000 and Taxi 312323. We thank all members of the physical and recreational therapy departments, medical staff and psychologist of the participating centres for their collaboration. A special feeling of gratitude to Marjan van Aken, Ine van den Berg, Corrien Duin, Jacolien Eelman, Karin Gaasbeek, Lard Plasmans, Anne Shumway-Cook and Gerda van

Vliet, who critically commented on the manuscript. Most of all we would like to thank all the people who participated in one of the interventions.

References

1 Hag S ten, Toet H, Hartog PC den. Prive-ongevallen bij senioren: Een overzicht van sterfte en letsel door prive-ongevallen bij personen van 55 jaar en ouder. Amsterdam: Stichting Consument en Veiligheid, 1998.
2 Howland J, Lachman ME, Peterson EW, Cote J, Kasten L, Jette A. Covariates of fear of falling and associated activity curtailment. *J Gerontol B Psychol Sci Soc Sci* 1998; **53**(6): 384–92.
3 Vellas BJ, Wayne SJ, Baumgarter RN, Garry PJ. Fear of falling and restriction of mobility in elderly fallers. *Age Ageing* 1997; **26**(3): 189–93.
4 Tinetti ME, Williams FT, Mayewski R. Fall risk index for elderly patients based on number of chronic disabilities. *Am J Med* 1986; **80**: 429–34.
5 Duncan PW, Chandler J, Studenski S, Hughes M, Prescott B. How do physiological components of balance affect mobility in elderly men? *Arch Phys Med Rehabil* 1993; **74**: 1343–49.
6 Tinetti ME, Ginter SF. Identifying mobility dysfunctions in elderly patients. *JAMA* 1988; **259**: 1190–93.
7 Wickham C, Cooper C, Margetts M, Barker DJP. Muscle strength, activity, housing and the risk of falls in elderly people. *Age Ageing* 1989; **18**: 47–51.
8 Kempen GIJM, Verbrugge LM, Merrill SS, Ormel J. The impact of multiple impairments on disability in community-dwelling older people. *Age Ageing* 1998; **27**: 595–604.
9 Lenders JWM, Hiefnagels WHL, Thien TH. Orthostatische hypotensie bij bejaarden. *Nederlands Tijdschrift voor Geneeskunde* 1990; **134**(26): 1252–54.
10 Gerson LW, Jarjoura D, McCord G. Risk of imbalance in elderly people with impaired hearing or vision. *Age Ageing* 1989; **18**: 31–34.
11 Woollacott MH, Shumway-Cook A. Changes in postural control across the lifespan – a systems perspective. *Phys Ther* 1990; **70**: 799–807.
12 Berg K, Wood-Dauphinee S, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. *Can J Public Health* 1992; **83**: S7–S11.
13 Berg K, Maki B, Williams JI, Holliday PJ, Wood-Dauphinee S. Clinical and laboratory measures of postural balance in an elderly population. *Arch Phys Med Rehabil* 1992; **73**: 1073–80.
14 Duncan PW, Studenski S, Chandler J, Prescott B. Functional reach: predictive validity in a sample of elderly male veterans. *J Gerontol Med Sci* 1992; **47**(3): M93–98.
15 Bogle Thorbahn LD, Newton RA. Use of the Berg Balance Test to predict falls in elderly persons. *Phys Ther* 1996; **76**: 576–85.
16 Shumway-Cook A, Baldwin M, Polissar N, Gruber W. Predicting the probability for falls in community-dwelling older adults. *Phys Ther* 1997; **77**(8): 812–19.
17 Myers AM, Powell LE, Maki BE, Holliday PJ, Brawley LR, Sherk W. Psychological indicators of balance confidence: relationship to actual and perceived abilities. *J Gerontol Med Sci* 1996; **51A**: M37–43.
18 Topp R, Mikesky A, Wigglesworth J. The effect of a 12-week dynamic resistance strength training program on gait velocity and balance of older adults. *Gerontologist* 1993; **33**: 501–506.
19 Judge J, Whipple R, Wolfson L. Effects of resistive and balance exercises on isokinetic strength in older persons. *J Am Geriatr Soc* 1994; **42**: 937–46.
20 Westhoff M, De Loor S, Miedema M, Boshuizen H. Ontwikkeling van een krachttrainingsprogramma voor ouderen ter versterking van de M.qadriceps femoris. *Ned T Fysiother* 1998; **108**(6): 148–54.
21 Hu MH, Woollacott MH. Multisensory training of standing balance in older adults: 1. Postural stability and one-leg stance balance. *J Gerontol* 1994; **49**(2): M52–61.
22 Harada N, Chiu V, Fowler E, Lee M, Reuben DB. Physical therapy to improve functioning of older people in residential care facilities. *Phys Ther* 1995; **75**: 830–39.
23 Shumway-Cook A, Grubner 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.
24 Shumway-Cook A, Woollacott M. *Motor-control – theory and practical applications*. Baltimore: Williams & Wilkins, 1995.
25 Berg K, Wood-Dauphinee S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can* 1989; **41**: 304–11.
26 Berg K, Wood-Dauphinee S, Williams I. The balance scale: reliability assessment with elderly residents and patients with an acute stroke. *Scand J Rehabil Med* 1995; **27**: 27–36.
27 Stevenson TJ, Garland SJ. Standing balance during internally produced perturbations in subjects with hemiplegia: validation of the balance scale. *Arch Phys Med Rehabil* 1996; **77**.
28 Harada N, Chiu V, Damron-Rodriguez J, Fowler E, Siu A, Reuben DB. Screening for balance and mobility impairment in elderly individuals living in residential care facilities. *Phys Ther* 1995; **75**: 462–69.
29 Zigmund AS, Snaith RP. The Hospital Anxiety and Depression scale. *Acta Psychiatr Scand* 1983; **67**: 361–70.

30 Spinhoven P, Ormel J, Sloekers PP, Kempen GI, Speckens AE, Van Hemert AM. A validation study of the Hospital Anxiety and Depression Scale (HADS) in different groups of Dutch subjects. *Psychol Med* 1997; **27**(2): 363–70.
31 Wilkinson L. *Systat version 8*. Evanston: SPSS Inc, 1998.
32 Willems DA, Vandervoort AA. Balance as a contributing factor to gait speed in rehabilitation of the elderly. *Physiother Can* 1996; **48**: 179–84.
33 Tennstedt S, Howland J, Lachman M, Peterson E, Kasten L, Jette A. A randomised, controlled trial of a group intervention to reduce fear of falling and associated activity restriction in older adults. *J Gerontol B Psychol Sci Soc Sci* 1998; **53**(6): 384–92.
34 Mulder T, Berndt H, Pauwels J, Nienhuis B. Sensorimotor adaptability in the elderly and disabled. In: Stelmach G, Homberg V eds. *Sensorimotor impairment in the elderly*. Dordrecht: Kluwer, 1993: 413–26.
35 De Weerdt W, Spaepen A. Balance. In: Durward B, Baer G, Rowe P eds. *Functional human movement: measurement and analysis*. Oxford: Butterworth and Heinemann, 1999 203–18.

Appendix 1 – Characteristics of the Berg Balance Scale

Item	Description	
1)	sitting to standing	
2)	standing unsupported	
3)	sitting unsupported feet on floor	
4)	standing to sitting	
5)	transfers	
6)	standing unsupported with eyes closed	
7)	standing unsupported with feet together	
8)	reaching forward with outstretched arm	
9)	pick up object from the floor	
10)	turning to look behind/over left and right shoulders	
11)	turn 360 degrees	
12)	stool touch	
13)	standing unsupported, one foot in front	
14)	standing on one leg	
total score:		56

Appendix 2 – Characteristics of the Dynamic Gait Index

Item	Description	
1)	gait level surface	
2)	change in gait speed	
3)	gait with horizontal head turns	
4)	gait with vertical head turns	
5)	gait and pivot turn	
6)	step over obstacle	
7)	step around obstacle	
8)	stairs	
total score:		24

Appendix 3

The following model is used:

$$Y = XB + E$$

where Y is the $n \times 3$ response matrix (n is the number of observations), X is the $n \times 2$ design matrix, B is the 2×3 parameter matrix and E is the $n \times 3$ matrix of residuals. Each element of the first column of X equals 1 and the elements of the second column are either 1, for the first treatment, or −1, for the second treatment. The first row of B contains the overall means (i.e. averaged over the two treatments) at the three times and the second row the differences between the two treatment means at all three times. The two-sample t-tests are hypotheses on the specific form of the parameter matrix B. The first hypothesis states that the difference between the elements b_{21} and b_{22} is zero, i.e. it assumes that the difference between treatment groups does not change in the first period. The second hypothesis is very similar and assumes that there is no difference between b_{22} and b_{23}.