Effects of a Structured Exercise Programme on Functional Balance in Visually Impaired Elderly Living in a Residential Setting

Ken K.W. Cheung,[1] PDPT; **Kai Y. Au**,[1] MSc, BScPT; **Wilson W.S. Lam**,[1] MSc, BScPT;
Alice Y.M. Jones,[2] PhD, FACP

Abstract: One major priority for health care professionals is to minimize the risk of fall in the elderly population. While the quality of life of an individual is affected by fall accidents, management of post-fall disability in the elderly could be a huge economic burden to the society. Visually impaired elderly are at a higher risk of fall, because "vision", an important component contributing to balance, is disturbed. The aim of this study was to examine the effects of an exercise programme, which focused on improvement of the functional balance of visually impaired elderly. Visually impaired elderly residents were randomly assigned to either the exercise training or control group. A multidimensional, individually tailored exercise programme was introduced by physiotherapists to the exercise group for 12 weeks. Functional balance status reflected by the Berg Balance Scale, chair stand test, and timed up-and-go test assessed before and after the 12-week training programme was compared between the two groups. Results demonstrated a significant improvement in balance outcomes in the exercise group ($p < 0.05$) but not in the control group. The results of this study suggest that a physiotherapist-designed strengthening and balance-training programme can improve the functional balance status of visually impaired elderly.

Key words: balance, elders, exercise, impairment, visual

Introduction

Improvements in living standards and advances in medicine have resulted in increasing longevity; however, this is accompanied by deteriorating physical health including muscle strength, flexibility and exercise endurance. This, in part, is responsible for the increase in demand for rehabilitation and residential services, and indeed, the number of individuals residing in "subvented" care and attention homes for the aged has been increasing [1]. The elderly population is at high risk of falls and injuries [2–4]; at age above 65, one in three persons was reported to fall at least once a year, and this increased to one in two persons in people above 80 years of age [5]. In Hong Kong, a study conducted by the Hospital Authority showed that the overall "fall rate" in hospitals ranged from 0.66 to 0.71 per 1,000 patient-bed days. This fall rate increased from 0.71 in the age group of 60–69 years to 1.49 in the age group of 80–89 years [6].

Injuries that result from falls could lead to serious physical and psychological consequences, including impaired mobility, restricted activity and functional decline, as well as the vicious cycle of fear of repeated falls [7]. Fall is thus one major contributing factor to elderly disability that leads to a decrease in quality of life [8].

It was reported that 89% of fall-related injuries were fractures [9], of which hip fractures accounted for 50%. In Hong Kong, 92% of all fractures of the femur neck were sustained by the elderly [10]. In the USA, the annual cost of management of hip fractures was reported to be $9 billion, and 90% of these hip fractures were caused by falls [11]. In general, risk factors associated

[1]The Hong Kong Society for the Blind, and [2]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong SAR, China.
Received: 12 August 2008 Accepted: 18 December 2008
Reprint requests and correspondence to: Dr Alice Jones, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR, China.
E-mail: rsajones@polyu.edu.hk

ELSEVIER

with falls are either intrinsic or extrinsic. Intrinsic factors include changes in muscular strength [12–14], decreased joint flexibility [15,16], gait and balance problems, cognitive impairment [17], depression [14], impaired visual sensation [14,18], decline in vestibular function [19,20], decreased vibratory sense [21], and side effects of medications [14,22]. Extrinsic factors include environmental factors such as poor lighting, slippery floor, uneven walking surface and, obviously, obstacles.

Amongst elderly populations, while gait and balance impairment are considered to be the most significant risk factor associated with falls [23], visual impairment is an important risk factor of falls [24] and hip fractures [25]. Adequate depth perception and distant edge contrast sensitivity are important elements for maintenance of balance and assessing the safety of the environment [24]. It was reported that the main determinants of recurrent falls were: abnormal postural sway; two or more falls in the previous year; weak handgrip strength; and a depressive state of mind [26].

Exercises for improvement of balance are the mainstay for prevention of falls [27,28]. While there are numerous reports on exercise programmes for improvement of strength and balance in the elderly, programmes specially designed for people with visual impairment are scant. A recent study reported the cost-effectiveness of a home programme for people with severe visual impairment [29], but this programme failed to demonstrate a reduction in falls in their subjects. People with visual impairment are subject to a greater fear of falling than non-visually impaired people, and this fear in turn leads to the consequence of further decreased mobility. The aim of this study was to design, for elderly people with visual impairment, an effective exercise programme that will improve balance and increase confidence of safe ambulation, which would ultimately enhance independent mobility in this population.

Methods

Visually impaired subjects (people with no light perception or with visual acuity of 6/120 or worse on the better eye with corrective device), aged 65 years or older, from four care and attention homes, were invited to participate in the study. As only 30% of the residents in the involved elderly homes were male, to avoid effects due to mismatch of sex, it was decided that only female subjects would be recruited. All subjects were independently mobile. Those who suffered from painful conditions that affected their mobility or balance, neurological disorders, musculoskeletal problems, cardiovascular disease, unstable blood pressure associated with posture or mental conditions which limited them from following the exercise instructions, were excluded from the study.

The nature of the study was explained and subjects were told that the purpose of the study was to investigate the effects of two exercise programmes. (The exercise time for the two groups was different; therefore, they had no knowledge of the exercise format or protocol of the other group.) Written consent was obtained from all subjects prior to the commencement of the study. Participants were randomly assigned to either the exercise training group or the control group by drawing from a sealed opaque envelope that contained the number that determined the allocation.

The exercise group received a structured individually tailored exercise programme designed by a physiotherapist, in addition to their routine group physical activity. The control group only participated in the routine group physical activity. Exercise programmes were designed and conducted by two physiotherapists, and assessment of the functional status of the subjects was conducted by a third physiotherapist who was blinded to the grouping of the subjects. All three physiotherapists have at least 6 years' experience in the rehabilitation of visually impaired elderly.

Exercise protocol

The exercise protocol was specially designed to improve functional balance as well as muscle strength of individuals, with an aim to assist the subject to cope with daily function under impaired vision. The protocol included: (1) warm up—range of motion and stretching exercises for the upper limbs in a sitting position, lower limb warm up exercise including quadriceps and calf stretching, and ankle circumduction in a standing position; (2) lower limbs strengthening exercises—chair stand exercise (sets of five repetitions progressing to 10 repetitions), quadriceps strengthening in a sitting position, strengthening of hip extensors and abductors in a standing position, with cuff weights in three sets of 10 repetitions with progressive weights (e.g. 10 repetitions with 3 pounds, then 5 pounds, followed by 7 pounds, based on the capacity of the individual subject); (3) balance exercises—supervised stool stepping exercise, tandem standing, and single leg standing; and (4) cool down exercises—general stretching and mobility exercise. Balance exercise was progressed based on the subject's needs and according to the ability of the subject. For example, one subject might focus on the stool stepping exercise, while another might focus on single leg standing training. As the subjects were visually impaired, verbal guidance as well as manual physical assistance when performing the balance training was provided. The duration of the training programme was three times a week for 12 weeks, and each session lasted 45 minutes.

Apart from the individual tailored exercise programme, these subjects continued to participate in the routine standard exercise programme that is organized for all residents of the home. The standard programme

Table 1. Mean (standard deviation) score, mean (standard deviation) difference within groups, and mean (95% confidence interval) difference between groups for all outcomes for the experimental group (n=27) and the control group (n=23)

Outcome	Groups				Difference within groups		Difference between groups
	Pre		Post		Post minus pre		Post minus pre
	Exp	Con	Exp	Con	Exp	Con	Exp minus Con
BBS score	43.30 (5.17)	43.30 (5.03)	48.56 (4.40)	44.26 (5.21)	5.26 (2.67)	0.96 (2.16)	4.3 (2.90 to 5.70)
TUG (s)	28.25 (13.67)	26.07 (14.08)	23.55 (11.28)	26.13 (14.99)	–4.70 (6.76)	0.06 (3.44)	–4.76 (–7.90 to –1.63)
CST (s)	17.78 (5.51)	20.14 (11.80)	14.17 (4.62)	18.87 (13.55)	–3.61 (3.72)	–1.26 (4.32)	–2.35 (–4.67 to –0.03)

Exp = experimental; Con = control; BBS = Berg Balance Scale; CST = chair stand test; TUG = timed up-and-go test.

included three sessions of 45–60 minutes of general exercise (upper limb and lower limb mobilization exercises using shoulder pulley and floor bike/static bike) per week. All subjects in the control group participated in this routine general exercise programme.

Measurement outcomes

Balance and muscle strength before and after the 12-week exercise programme included: (1) Berg Balance Scale (BBS) [30], which rated the performance of 14 specific tasks; and (2) the timed up-and-go test (TUG) [31], which measured the time required to get up from a seated position and walk 3 m (two trials were allowed and the time required in two trials was averaged). The "functional" muscle strength of each subject was assessed by the chair stand test (CST) [32]. The subject sat on a standard chair without armrests. On the command "go", the subject stood up fully, then sat down, and was asked to repeat the cycle five times unaided. The subject was instructed to perform the test as quickly as they felt comfortable. The time required to complete the five cycles of standing and sitting was recorded. The interrater reliability of the BBS, TUG and CST was conducted in a pilot test prior to data collection. Results showed that the intraclass correlation coefficient (2,2) for the three measures were 0.821, 0.955 and 0.965, respectively, suggesting that these tests are reliable.

Statistical analysis

Within-group scores from the first and second measurements of the BBS, CST and TUG were compared by the paired t test, and between-group data were compared with the independent t test. The correlation amongst the three outcome measures were tested by Pearson's correlation coefficient. The statistical significant value was set at 0.05. Data were analysed by SPSS version 14 (SPSS Inc., Chicago, IL, USA) for Windows.

Results

Fifty female subjects were recruited into the study. Twenty-seven were allocated to the exercise training group and 23 to the control. There were no falls in either group during the study period. All subjects completed the full 36 training sessions. The mean (± standard deviation) age for the training and control groups was 83 (±4.7) and 84.4 (±6.5) years, respectively. There were no significant differences between the training and control groups in age ($p = 0.377$) and pre-training scores of the BBS, CST and TUG (Table 1).

This study showed that subjects in the exercise group demonstrated a 9.4% improvement in BBS scores ($p < 0.000$) and a decrease in the time of TUG by 4.7 seconds ($p < 0.003$). The change in these scores in the control group was, however, not significant (Table 1). The training group also showed significant improvement in CST when compared with the control group (mean time difference, 2.35 seconds; $p = 0.047$; 95% confidence interval [CI], 0.03–4.67). There were good correlations amongst the BBS score, TUG and CST data ($p < 0.0001$) (Table 2).

It was reported that people with BBS score < 45 were 2.7 times more likely to suffer multiple falls compared with those who scored ≥ 45 [33]; therefore, subjects with BBS score < 45 were subjected to further analysis. Of the 13 subjects whose pre-training BBS score was < 45, eight of them (61.5%) reached a BBS score > 45 after training (Figure). This subgroup of 13 subjects showed an average improvement of 6.38 (± 3.3) points. Those with pre-training BBS score ≥ 45 had a mean improvement of only 4.21 (± 1.4) points. The difference in the improvement of BBS score between these two groups was also statistically significant ($p = 0.032$; 95% CI, 0.21–4.14).

For the control group, 12 subjects had an initial BBS score < 45. Only two of these 12 subjects had their final

Table 2. Correlation between Berg Balance Scale (BBS), chair stand test (CST) and timed up-and-go test (TUG) data

	CST	BBS	TUG
TUG			
Pearson's correlation	0.761*	−0.714*	1.00
Significance (two-tailed)	0.000	0.000	
n	50	50	50
BBS			
Pearson's correlation	−0.641*	1.00	−0.714*
Significance (two-tailed)	0.000		0.000
n	50	50	50
CST			
Pearson's correlation	1.00	−0.641*	0.761*
Significance (two-tailed)		0.000	0.000
n	50	50	50

*Correlation is significant at the 0.01 level (two-tailed).

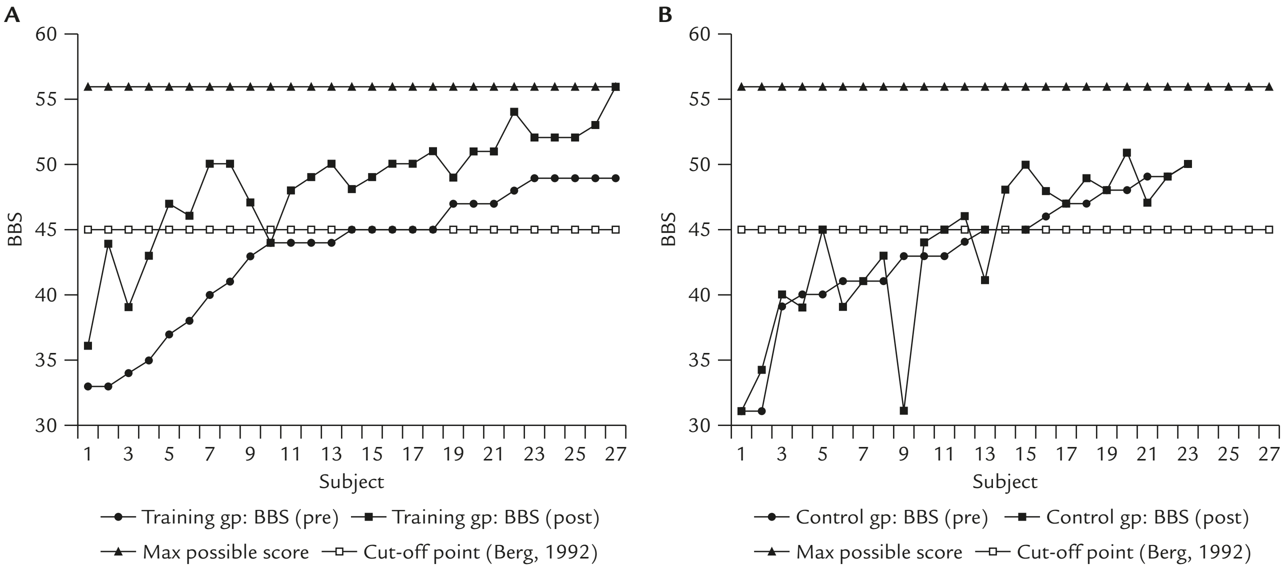

Figure. Pre- and post-training Berg Balance Scale (BBS) scores of subjects in the: (A) exercise training group; (B) control group.

BBS score raised to ≥45 at the end of the intervention period (Figure).

Discussion

The results of this study suggest that a physiotherapist-designed exercise programme significantly improved balance in our visually impaired elderly subjects. Subjects with weaker balance (BBS score <45) showed better improvement than those who were more stable. This is not surprising, as the programme was specially designed based on the need of the subject. While warm up exercise and muscle strengthening could be conducted in class and with minimal assistance, balance training in our intervention group required one-to-one therapist-to-client supervision. Although this may be manpower-demanding, it is considered cost-effective as the mobility of the elderly subject is enhanced with safety ensured and the risk of fall is ultimately reduced.

It was found that elderly people who scored below 45 on the BBS were 2.7 times more likely to experience multiple falls when compared with those who scored 45 or above [33]. Our study showed that 61.5% of our subjects raised their BBS to above 45 after 36 sessions of strengthening and balance training, suggesting that our exercise programme has the potential to prevent falls in our visually impaired elderly population.

Previous studies showed that exercise programmes could reduce the risk of falls among community dwelling elderly [2,27,34,35]; the rate of falls was lower by 77% in those who exercised at least three times a week compared with those who exercised less than once a week [29]. We have adopted the optimal frequency of three exercise sessions a week. As the subjects in our study cohort were in care and attention homes, they were well taken care of by nurses and carers; thus, rate of falls was not an appropriate outcome measure in this study over a 12-week period.

Our record showed that a total of 12% of residents in these four care and attention homes had a history of hip fractures associated with fall accidents. This proportion is alarmingly high. There is, therefore, a need to improve the muscle strength, balance and confidence for independent mobility in this elderly population. Maintenance of active and independent mobility is essential to maintain the quality of life of elderly people [36], and this will also decrease the manpower resources required in a care and attention home.

Muscle strength is an important component of balance. Our exercise programme mainly focused on lower limb strengthening exercises and balance exercises using environmental facilities familiar to the visually impaired elderly.

We were pleased that over 60% of our subjects achieved a BBS score of over 45 after 36 sessions of exercise training. The high correlation among BBS score, CST and time required for completion of the TUG suggest that improved balance is associated with lower limb strength and improved activity performance, further supporting our hypothesis that our exercise programme is able to enhance mobility.

Study limitations

As the sample was drawn from a female population in residential care, the result may not be generalizable to other community-dwelling elderly with visual impairment. Further investigation of elderly people with impaired vision residing independently at home is necessary.

Conclusion

This study showed that a structured and individualized balance and strength training exercise programme designed by physiotherapists improved the balance status of elderly people with impaired vision living in residential institutions.

Acknowledgements

The authors are indebted to Mr Brian Choi for his untiring support and assistance in the statistical analysis of the data.

References

1. *Hong Kong Year Book 2002.* Available at: http://www.yearbook.gov.hk/2002/ehtml/e10-frame.htm [Date accessed: December 2007]
2. Tinetti ME, Baker DI, McAvay G, et al. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. *N Engl J Med* 1994;331:821–7.
3. Hornbrook MC, Stevens VJ, Wingfield DJ, et al. Preventing falls among community-dwelling older persons: results from a randomized trial. *Gerontologist* 1994;34:16–23.
4. Blake AJ, Morgan K, Bendall MJ, et al. Falls by elderly people at home: prevalence and associated factors. *Age Ageing* 1988; 17:365–72.
5. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988;319:1701–7.
6. Hospital Authority Head Office. *Report on Falls in Acute Wards, 2002.* Hong Kong: Hospital Authority, 2002.
7. Vellas BJ, Wayne SJ, Romero LJ, et al. Fear of falling and restriction of mobility in elderly fallers. *Age Ageing* 1997;26: 189–93.
8. Berg K. Balance and its measure in the elderly: a review. *Physiother Can* 1989;41:240–6.
9. Peel NM, Kassulke DJ, McClure RJ. Population based study of hospitalised fall related injuries in older people. *Inj Prev* 2002;8:280–3.
10. Hospital Authority. *Top Disease Burden (General Disease), 1998.* Hong Kong: Hospital Authority, 1998.
11. Sandler R, Robinovitch S. An analysis of the effect of lower extremity strength on impact severity during a backward fall. *J Biomech Eng* 2001;123:590–8.
12. Whipple RH, Wolfson LI, Amerman PM. The relationship of knee and ankle weakness to falls in nursing home residents: an isokinetic study. *J Am Geriatr Soc* 1987;35:13–20.
13. Aniansson A, Grimby F, Gedberg A. Muscle function in old age. *Scand J Rehabil Med* 1978;6(Suppl):43–9.
14. Rubenstein LZ, Josephson KR. The epidemiology of falls and syncope. *Clin Geriatr Med* 2002;18:141–58.
15. Guralnik JM, Ferrucci L, Simonsick E, et al. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med* 1995;332:556–61.
16. Lewis C, Bottomley J. Musculoskeletal changes with age. In: Lewis C, ed. *Aging: Health Care's Challenge*, 2nd edition. Philadelphia, PA: FA Davis Co., 1990;145–6.
17. Verghese J, Buschke H, Viola L, et al. Validity of divided attention tasks in predicting falls in older individuals: a preliminary study. *J Am Geriatr Soc* 2002;50:1572–6.
18. Kosnik W, Winslow L, Kline D, et al. Visual changes in daily life throughout adulthood. *J Gerontol* 1988;43:63–70.
19. Sloane PD, Baloh RW, Honrubia V. The vestibular system in the elderly: clinical implications. *Am J Otolaryngol* 1989;10:422–9.
20. Ochs AL, Newberry J, Lenhardt ML, et al. Neural and vestibular aging associated with falls. In: Birren JE, Schaie KW, eds. *Handbook of Psychology of Aging*. New York, NY: Van Nostrand Reinhold, 1985;378–99.
21. Whanger AD, Wang HS. Clinical correlates of the vibratory sense in elderly psychiatric patients. *J Gerontol* 1974;29:39–45.
22. Parra EK, Stevens JA. *U.S. Fall Prevention Programs for Seniors: Selected Programs Using Home Assessment and Home Modification.* Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2000.
23. Rubenstein LZ, Josephson KR, Robbins AS. Falls in the nursing home. *Ann Intern Med* 1994;121:442–51.
24. Lord SR, Dayhew J. Visual risk factors for falls in older people. *J Am Geriatr Soc* 2001;49:508–15.
25. Abdelhafiz AH, Austin CA. Visual factors should be assessed in older people presenting with falls or hip fracture. *Age Ageing* 2003;32:26–30.

26. Stalenhoef PA, Diederiks JP, Knottnerus JA, et al. A risk model for the prediction of recurrent falls in community-dwelling elderly: a prospective cohort study. *J Clin Epidemiol* 2002;55:1088–94.
27. Wolf B, Feys H, De Weerdt W, et al. Effect of a physical therapeutic intervention for balance problems in the elderly: a single-blind, randomized, controlled multicentre trial. *Clin Rehabil* 2001;15:624–36.
28. Cumming RG. Intervention strategies and risk-factor modification for falls prevention: a review of recent intervention studies. *Clin Geriatr Med* 2002;18:175–89.
29. Campbell AJ, Robertson MC, La Grow SJ, et al. Randomised controlled trial of prevention of falls in people aged ≥75 with severe visual impairment: the VIP trial. *BMJ* 2005;331:817.
30. Berg KO, Maki BE, Williams JI, et al. Clinical and laboratory measures of postural balance in an elderly population. *Arch Phys Med Rehabil* 1992;73:1073–80.
31. Wall JC, Bell C, Campbell S, et al. The Timed Get-up-and-Go test revisited: measurement of the component tasks. *J Rehabil Res Dev* 2000;37:109–13.
32. Aoyagi K, Ross PD, Nevitt MC, et al. Comparison of performance-based measures among native Japanese, Japanese-Americans in Hawaii and Caucasian women in the United States, ages 65 years and over: a cross-sectional study. *BMC Geriatr* 2001;1:3.
33. Berg KO, Wood-Dauphinee SL, Williams JI, et al. Measuring balance in the elderly: validation of an instrument. *Can J Public Health* 1992;83(Suppl 2):S7–11.
34. Buchner DM, Cress ME, de Lateur BJ, et al. The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. *J Gerontol A Biol Sci Med Sci* 1997;52:M218–29.
35. Campbell AJ, Robertson MC, Gardner MM, et al. Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *BMJ* 1997;315:1065–9.
36. Adamson J, Lawlor DA, Ebrahim S. Chronic diseases, locomotor activity limitation and social participation in older women: cross sectional survey of British Women's Heart and Health Study. *Age Ageing* 2004;33:293–8.