Comparison of balance in older people with and without visual impairment

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Abstract

Objective: a cross-sectional study was used to compare the balance ability of older people with and without visual impairment.

Setting: Tung Wah Group of Hospitals Jockey Club Rehabilitation Complex and the Pok Oi Hospital Jockey Club care and attention homes for aged individuals.

Subjects: a total of 66 subjects, 65 years of age and older, were divided into three groups based on their degree of visual impairment.

Methods: the directional Es chart was used to test the subjects’ visual acuity. Functional balance ability was measured using the Berg balance scale. Demographic characteristics and baseline variables such as lower extremity range of motion, muscle strength, and joint pain was assessed and compared between the groups.

Results: 66 older adults (43 women, 23 men) aged 69–94 years of age participated in the study. The one-way ANOVA showed that the mean Berg balance scores were significantly different (F(2,63) = 19.19, P < 0.001). Post hoc tests showed that the group with no visual impairment had higher mean balance scores than the group with mild visual impairment (P = 0.04) and those with moderate visual impairment (P < 0.001). The balance scores for the group with mild visual impairment were also shown to be significantly different from those of the group with moderate visual impairment (P = 0.003). Control of factors related to balance, such as range of motion, pain and strength, did not affect the analysis of variance analyses.

Conclusions: balance was shown to be more impaired with greater visual impairment, which could result in falls and resultant injury. The findings suggest that early intervention to improve visual acuity in older people may be important.

Keywords: visual impairment, visual acuity, functional balance ability

Introduction

Balance is required for maintaining a position, remaining stable while moving from one position to another, performing activities of daily living, and moving freely. However, a decline in balance ability has been shown to occur with increasing age [1–4]. Bogle and Newton [5] found that impaired balance was correlated with an increased risk of falls and an increased mortality rate in older persons who were prone to fall when compared with those who were not prone to fall. Moreover, postural disturbances frequently result in falls and may consequently lead to negative consequences, such as injuries and mortality, especially in the older population [6–9].

Several studies have identified visual impairment as a contributing factor to the occurrence of falls in the elderly [10–13]. It has been shown that vision plays an important role in balance, mobility, and falls [14]. Older people with blindness have demonstrated a higher rate of falls than those with deafness or those with no visual and hearing impairment [7]. Gaebler [15] showed that visual and hearing impairment was related to the frequency of falls. There is a high prevalence of low vision in older patients who were admitted to an acute geriatric unit with falls, as well as in older people who attend outpatient clinics [16, 17].

A large study of older residents of three communities showed that limitations in mobility, activities of daily living, and physical performance were associated with worse visual function [18]. More recently, the standing balance in older persons in nursing homes, as measured by amount of sway, was shown to be worse for those who have visual impairment [19]. Also, a longitudinal study demonstrated that the balance skills were lower...
among subjects who were legally blind than among those with minimal sight [20]. However, the seven subjects with minimal sight who participated in this study did not have their vision measured objectively.

All of these studies in some way assessed the effect that vision has on balance, however, few stated that visual impairment was assessed in an objective manner and not all used balance tests that were functionally relevant.

Apart from vision, several intrinsic factors have been shown to be related to balance control in the older adults. These included age, sex, height, body mass index, muscle strength, range of motion, endurance and pain [9, 12, 21–27]. However, it was not known to what extent limited range of motion contributes to instability in older people [8, 21]. Severe chronic diseases, neurological conditions, middle ear problems, postural hypotension, side effects of medications, abnormal mental status and fear of falling have also been shown to be factors related to balance control [21, 25, 26, 28, 29].

Although several studies support that balance ability decreases with age and that older people with some visual impairment have a higher rate of falls, little is known about the balance ability in older people with different levels of visual impairment. The purpose of this study was to compare the balance ability in older people with no visual impairment, mild visual impairment and moderate visual impairment.

Methods

Subjects

Sixty-six older adults volunteered to participate in the study. A convenience sample was used and all the subjects who volunteered lived in one of six care and attention homes for aged individuals in the Jockey Club Rehabilitation Complex or the Pok Oi Hospital Jockey Club care and attention homes for aged individuals. Care and attention homes provide residence to older adults who cannot live independently in the community, but are not bed-ridden.

The inclusion criteria included subjects who were 65 years of age or older and able to follow simple directions, for example, left, right, up or down. The exclusion criteria included people with functional blindness (acuity level worse than 20/200) and those with major chronic medical or physical conditions, including rheumatoid arthritis or osteoarthritis, severe low back pain, severe lower limb deformities, as diagnosed by a physician, which resulted in the inability to ambulate independently or with the use of an assistive device. Those who were non-ambulatory, had an amputation or had been diagnosed with Parkinson’s disease, stroke, severe dementia or vestibular problems, as well as those with poor memory were also excluded.

All eligible subjects were provided with a letter of information describing the study or the information was verbally relayed to them in the event that they were illiterate or unable to see well enough to read the letter. All participants signed or made a mark on the consent form prior to participating in the study. The study was approved by the ethics review board of the Hong Kong Polytechnic University and the superintendents of the participating care and attention homes.

Measurement

All of the measurements were taken in the afternoons at approximately the same time of the day. They were administered by one experienced physiotherapist in a quiet, bright examination room. Information on gender, age, type of walking aid, and the cause of the visual problem for those with visual impairment, as documented on the medical examination report, was determined. The subject’s weight and height was also measured.

Visual acuity and balance ability was then measured. The directional Es chart was used to assess visual acuity (Figure 1)[30]. This test is not literacy-dependent and is widely used in China or with people who are illiterate [30]. The directional Es chart examines central vision in both eyes at the same time as the bilateral visual function [18, 31]. The E chart has been used as a standardised test for the measurement of visual acuity [18, 32–36]. The test was carried out with the subjects seated and the chart set at the subject’s eye level five meters away. The subject was asked to determine the location of the open end of

![Figure 1. Directional Es chart (note: the size of the chart is not to scale) [30].](https://academic.oup.com/ageing/article-abstract/32/6/643/13056)
the letter E on the largest, top line. If the answers were correct, the subject was required to read the next smaller line until the smallest line was reached. The directional Es chart consisted of 12 lines. The visual acuity was scored as 0.1 if the subject could only determine the direction of the E on the first line and 1.0 if the subject could correctly see the tenth line. If the subject could read the whole eighth line, but could read less than one half of the ninth line, then visual acuity was 0.8. When a subject was unable to read the largest line on the chart from a five meters distance, test distance was shortened and a correction equation \[0.1 \times \text{test distance (in meters)/5}\] was used to calculate visual acuity. Following the visual acuity test, the subjects were classified into three groups according to the criteria set in Table 1.

The Berg balance scale was used to assess the balance ability of the subjects. It is a performance-based measure of balance consisting of 14 observable tasks [37–39]. All items are graded on a five-point ordinal scale (0–4 points), which give a total score ranging from 0–56 points. If the tasks required subjects to place the foot on a stool or to reach forward, the choice of which leg to stand on or how far to reach was decided by the subjects [37]. The examiner was allowed to demonstrate the task before the subject performed it. Ten of the subjects, with different levels of visual impairment were asked to complete the Berg balance test a second time, with the same rater, within one week in order to calculate intra-rater reliability.

Finally, the verbal numeric pain rating scale was administered, followed by the muscle testing and range of motion assessment. The verbal numeric pain rating scale was used to assess present pain intensity of the hip, knee and ankle. The scale ranged from zero (no pain) to 10 (worst pain imaginable). A standard goniometer was used to measure active range of motion at the hip, knee, and ankle joints. Standard methods [40] for measuring the joint range were used. The total active range of motion (TAM) for a particular joint was the sum of the flexion and extension range.

A calibrated hand-held dynamometer, the Nicholas manual muscle tester (MMT) model 01160 (Lafayette Instrument Company, Lafayette, IN 47903, USA) was used to test isometric muscle strength of the quadriceps, hamstrings and ankle dorsiflexors for each leg using standard techniques [41]. The MMT has a digital accuracy of ± 0.5% of full scale and a force range from 0.0 to 199.9 kg [42]. Before the actual test, the subjects were given a demonstration and one trial to familiarise themselves with the required action. During the test, the subject was instructed to raise the limb to a specific height and maximally resist the examiner’s efforts to depress it with the standard method and to hold it for three seconds [43, 44]. Each muscle strength test was repeated three times with a brief rest of one minute in between and the highest value was recorded.

### Statistical analysis

All analyses were carried out with the SPSS (Version 9.0) statistical software package. The ICC (3, 1), using the absolute agreement option, was calculated to determine the intra-rater reliability for the Berg balance test [45]. The means and standard deviations of the balance scores as well as the 95% confidence intervals for the mean differences in balance scores were calculated. A one-way ANOVA was performed to determine if there were any statistically significant differences in mean Berg balance scores between those with no visual impairment, mild visual impairment and moderate visual impairment. Multiple comparisons, using Scheffe’s test, were used to compare the balance scores between pairs of groups following a significant ANOVA result. For each of the factors listed in the introduction that may influence balance, an ANCOVA was performed to determine the effect of each of them on the relationship between balance and vision. A significance level for all statistical tests was set at 0.05.

### Results

A total of 10 subjects were invited to repeat the Berg balance test measurements with the same rater within a period of one week. The ICC (3, 1) for the intra-rater reliability of the Berg balance test was calculated to be 0.97.

### Demographic characteristics of the subjects

A total of 66 subjects, ranging in age from 69 to 94 years of age were recruited for the study, with 22 subjects in each of the three visual impairment subgroups (Table 2). Forty-three subjects (65.2%) were women and 23 subjects (34.8%) were men. The cause of visual problems in the subjects included cataracts (37.9%), glaucoma (10.6%), macular degeneration (25.8%), retinal detachment (4.5%), and unknown causes (22.2%). A similar proportion of the subjects were able to walk without the help of an assistive device (42%) or with a standard cane (44%). The remainder of the subjects either used a quadruped cane or a walker (14%) during ambulation.

<table>
<thead>
<tr>
<th>Group</th>
<th>Acuity (value in fraction)</th>
<th>Acuity (value in decimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No visual impairment</td>
<td>20/40 or better</td>
<td>≥0.5</td>
</tr>
<tr>
<td>Mild visual impairment</td>
<td>20/60 or better but</td>
<td>0.5 to ≥0.3</td>
</tr>
<tr>
<td>Moderate visual impairment</td>
<td>worse than 20/40</td>
<td>0.3 to ≥0.1</td>
</tr>
<tr>
<td>Functional blindness</td>
<td>Worse than 20/200</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>
Baseline measures
The descriptive statistics for the total active movement (TAM) for each joint of the lower extremity in each group are presented in Table 3. Those for isometric muscle strength for the knee flexion, knee extension and ankle dorsiflexion are presented in Table 4. Pain intensity ratings for the hip, knee and ankle ranged from zero to a maximum of four.

The Berg balance test
The mean Berg balance scores for the group with no visual impairment, the group with mild visual impairment and the group with moderate visual impairment were 50.73 (SD = 3.41), 45.55 (SD = 6.85) and 38.59 (SD = 8.31), respectively (Figure 2). The result of the one-way ANOVA showed that there was a significant difference in mean Berg balance scores between the three groups (F(2, 63) = 19.19, P < 0.001). The results of the post hoc Scheffé comparison tests revealed that there were significant differences in the mean balance scores between the group with normal vision and the group with mild visual impairment (P = 0.04, mean difference = 5.18, 95% CI 0.25, 10.11), between the group with no visual impairment and the group with moderate visual impairment (P < 0.001, mean difference = 12.14, 95% CI 7.21, 17.07) and between the group with mild visual impairment and the group with moderate visual impairment (P = 0.003, mean difference = 6.95, 95% CI 2.03, 11.88).

Age, gender, body mass index, the summary scores for the range of motion, the strength scores, and the pain scores were entered into separate ANCOVA models. After controlling for each individual factor, the same conclusion as the original one-way ANOVA regarding the difference in mean Berg balance scores resulted.

Discussion
This study provides evidence that level of visual acuity may affect balance in older Chinese people who reside in care and attention homes. These results are consistent with other studies studying the effect role of vision on balance in older people [7, 20]. Moreover, the results of this study are supported by a cross-sectional and cohort study, which reported that impaired visual function was associated with poor scores on the physical performance measures, that is,

Table 2. Demographic characteristics of the study sample

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender (% female)</th>
<th>Age (years) Mean (SD)</th>
<th>Height (m) Mean (SD)</th>
<th>Weight (kg) Mean (SD)</th>
<th>BMI (kg/m²) Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No visual impairment (n = 22)</td>
<td>(40.9)</td>
<td>77.27 (5.07)</td>
<td>1.58 (0.10)</td>
<td>59.96 (13.45)</td>
<td>23.81 (3.19)</td>
</tr>
<tr>
<td>Mild visual impairment (n = 22)</td>
<td>(81.8)</td>
<td>79.95 (6.28)</td>
<td>1.53 (0.09)</td>
<td>54.96 (10.58)</td>
<td>23.48 (3.55)</td>
</tr>
<tr>
<td>Moderate visual impairment (n = 22)</td>
<td>(72.7)</td>
<td>83.59 (6.22)</td>
<td>1.49 (0.10)</td>
<td>50.96 (11.82)</td>
<td>22.94 (4.49)</td>
</tr>
</tbody>
</table>

Table 3. Mean total active movement (TAM) by group.

<table>
<thead>
<tr>
<th>Joint</th>
<th>No visual impairment Mean degree (SD)</th>
<th>Mild visual impairment Mean degree (SD)</th>
<th>Moderate visual impairment Mean degree (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip</td>
<td>107.23 (8.31)</td>
<td>102.73 (9.00)</td>
<td>99.77 (11.87)</td>
</tr>
<tr>
<td></td>
<td>Left 107.82 (7.01)</td>
<td>98.50 (20.74)</td>
<td>97.95 (12.28)</td>
</tr>
<tr>
<td>Knee</td>
<td>136.09 (4.32)</td>
<td>130.32 (8.17)</td>
<td>128.95 (9.58)</td>
</tr>
<tr>
<td></td>
<td>Right 129.82 (26.85)</td>
<td>129.73 (5.53)</td>
<td>130.00 (9.67)</td>
</tr>
<tr>
<td>Ankle</td>
<td>44.59 (4.12)</td>
<td>39.68 (7.54)</td>
<td>40.68 (8.13)</td>
</tr>
<tr>
<td></td>
<td>Left 44.45 (4.74)</td>
<td>40.68 (8.87)</td>
<td>38.45 (8.73)</td>
</tr>
</tbody>
</table>

Table 4. Mean isometric muscle strength by group

<table>
<thead>
<tr>
<th>Joint</th>
<th>No visual impairment Mean kg (SD)</th>
<th>Mild visual impairment Mean kg (SD)</th>
<th>Moderate visual impairment Mean kg (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>11.45 (3.46)</td>
<td>9.38 (4.59)</td>
<td>10.32 (4.14)</td>
</tr>
<tr>
<td>Left</td>
<td>11.25 (4.27)</td>
<td>9.06 (4.07)</td>
<td>9.59 (3.88)</td>
</tr>
<tr>
<td>Knee flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>5.99 (2.33)</td>
<td>5.10 (2.77)</td>
<td>5.34 (3.01)</td>
</tr>
<tr>
<td>Left</td>
<td>5.50 (2.50)</td>
<td>4.63 (2.22)</td>
<td>4.98 (2.99)</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>5.67 (1.73)</td>
<td>5.41 (2.84)</td>
<td>5.79 (3.27)</td>
</tr>
<tr>
<td>Left</td>
<td>4.90 (1.63)</td>
<td>4.59 (2.28)</td>
<td>5.81 (3.24)</td>
</tr>
</tbody>
</table>

Figure 2. Boxplots for the Berg balance scores for the three groups based on degree of visual impairment.
standing balance and walking scores [18]. The results of the present study provide additional evidence that balance abilities, measured using a functional instrument, decline with a corresponding decline in visual function.

In the present study, it was observed, subjectively, that older people with no visual impairment, performed better and were more stable in some difficult items of the Berg balance test, for example, reaching an arm forward while standing, placing alternate foot on step or stool while standing unsupported, standing unsupported one foot in front, and standing on one leg. This observation was quite similar to that obtained by Berg and her co-workers [37]. Berg et al. [37] showed that the most difficult items for older patients to perform successfully were reaching an arm forward while standing, standing on one leg, and standing unsupported with one foot in front of the other. Therefore, it is likely that vision plays an important role in balance. It has also been shown that visual cues and visual information from the environment are an important source of feedback for balance skills [20, 27].

The scores obtained with the Berg balance scale appear to be appropriate as a score of <45 was shown to be predictive of multiple falls in older adults [46]. Thor-bahn and Newton [47] also pointed out that this cut-off score predicted a person’s use of an assistive device. In the present study, impaired balance score was related to the levels of visual impairment, and the result was consistent with the cut-off score of the above studies.

Furthermore, interventions such as exercise and balance training may be indicated in the visually impaired older people. Studies using exercise interventions in older people had shown improvement in balance, reaction time, strength, and flexibility [48, 49]. A recent research also demonstrated a significance of Tai Chi training in elderly persons to reduce the risk of falls [50]. Therefore, incorporating Tai Chi or other exercise interventions into balance training programmes for older people with visual impairment may be beneficial.

The limitations of this study should be addressed. The study was confined to older volunteers living in care and attention homes. In order to improve the generalisability of the results, further study with subjects from more and different types of centres in Hong Kong or from other ethnic groups is recommended. Also, a random sample of subjects should be selected from the participating centres.

Another limitation of this study was that only visual acuity of the subjects was measured. Apart from visual acuity, visual field, contrast sensitivity, depth perception, and glare impairment should be included in the examination of vision for the subjects [22]. These additional factors may also be a factor associated with balance performance. In addition, range of motion of the upper extremity and trunk as well as muscle strength of, for example, hip abduction, hip adduction, trunk flexion and extension, which were not tested in this study, should be incorporated into future studies.

The findings of the present study suggest that early intervention to improve the visual acuity of older people who are at risk for falls may be important. A randomised controlled trial study would need to be done to investigate whether early intervention to improve the visual acuity of older people improves balance and reduces falls. Assessing balance may have important implications for improving the quality of rehabilitation services for older people with visual impairment not only in care and attention homes, but also for older people with visual impairment living in other settings. Providing rehabilitation services aimed at maintaining or improving physical function and balance may be important to consider, especially for those older individuals with impaired vision. Standardised functional measures should be employed to assess not only balance, but also visual impairment in the screening for potential fallers among older people. Referrals to appropriate health care providers to treat or correct impaired vision, if possible, are also recommended.

Key points

- The functional balance of three groups of older adults, those with normal visual acuity, mild impairment in visual acuity and moderate impairment in visual acuity, were compared.
- Gender, age, height, and lower extremity range of motion was shown to be significantly different between the three groups of older adults and, therefore, were included as covariates in the analysis that examined differences in functional balance between the groups.
- Older people with moderate impairment in visual acuity were shown to have poorer functional balance compared with those with no or mild visual impairment.

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References


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