Objectives: we studied visual acuity (VA) and co-existing hearing impairment and poor standing balance as predictors of falls.

Design: prospective study with 1-year follow-up.

Setting: research laboratory and residential environment.

Participants: 428 women aged 63–76 years from the Finnish Twin Study on Aging.

Measurements: participants were followed up for incidence of falls over 1 year. VA, hearing ability and standing balance were assessed at the baseline. The incidence rate ratios (IRR) for falls were computed using the negative binomial regression model.

Results: during the follow-up, 47% of participants experienced a fall. After adjusting for age and interdependence of twin sisters, participants with vision impairment (VA of <1.0) but no other sensory impairments had a higher, but non-significant, risk for falls compared to persons with normal vision (IRR 1.5, 95% CI 0.6–4.2). Co-existing vision impairment and impaired balance increased the risk (IRR 2.7, 95% CI 0.9–8.0), as also did co-existing vision and hearing impairment (IRR 4.2, 95% CI 1.5–11.3), compared to those with normal vision. Among persons with all three impairments, the IRR for falls increased to 29.4 (95% CI 5.8–148.3) compared to participants with good vision.

Conclusion: the impact of vision impairment on fall risk was higher when accompanied with other sensory and balance impairments, probably because the presence of other impairments prevented the reception of compensatory information about body posture and environment being received from other sensory sources. When aiming to prevent falls and their consequences in older people, it is important to check whether poor vision is accompanied with other impairments.

Keywords: falls, vision, co-impairment, older adults, ageing, elderly
Introduction

Vision impairment is a common deficit in older adults and the leading causes of vision loss are age-related macular degeneration, cataract, glaucoma and diabetic retinopathy [1]. Previous studies have shown that decreased visual acuity (VA) is a significant predictor of falls, in particular recurrent falls and injurious accidents in community-dwelling older people [2, 3]. However, some previous studies have failed to detect a significant relationship between VA and fall incidence [4]. The other impairments associated with fall risk include balance and hearing. An association between poor balance and falls in old age has been observed in previous studies [5, 6], while some studies have reported no association [7]. Some studies have reported a significant association between hearing impairment and increased fall risk [8], but contrasting results have also been reported [9].

In old age, impairments often coincide. Thus far, the combined effects of poor vision and other sensory or balance impairments on fall risk are not known. Most of the recent studies have focused on the independent effects of sensory functions on fall risk, while only a few studies have investigated combined effects. In an earlier retrospective study, persons aged 70 or older with co-existing self-reported vision and hearing impairment were three times more likely to have fallen during the previous 12 months than persons without vision or hearing problems [10]. However, to the best of our knowledge, no previous prospective studies have been published on the combined effects of sensory impairments on fall risk.

Falls and their consequences have a major effect on older persons’ functional capacity and well-being [11], and therefore factors related to falls need to be well understood. The aims of the present study were to investigate the effect of visual impairment on fall risk and, further, the impact of co-existing vision loss and other sensory and balance impairments on fall incidence in a 1-year follow-up in relatively healthy community-living older women.

Methods

Participants

In the present study, 428 persons aged 63–76 years took part in fall surveillance for 1 year after tests of vision, hearing and balance. The recruitment of the participants is described in detail elsewhere [12, 13]. In brief, as part of the Finnish Twin Study on Aging (FITSA), the participants were drawn from the Finnish Twin Cohort, which comprises a total of 13,888 twin pairs. A total of 828 women were contacted of whom 434 took part. The inclusion required that participants were able to walk 2 km and independently travel to the research laboratory. We treated the sample as a set of individuals by adjusting all the analyses for within-pair dependence. The study was approved by the Ethical Committee of Jyväskylä Central Hospital Board.

Measures of vision

VA at a 5 m distance was measured in the research laboratory with and without participants’ own spectacles with the illuminated Landolt ring chart (Oculus 4512). Both eyes were examined separately. For this study, we used the best distance VA (with spectacles if needed). According to the standard definition of normal VA, the participants were categorized into those with visual impairment (VA < 1.0) and those with good vision (VA ≥ 1.0).

Audiometric measures

Audiometric measures were performed by an experienced audiology assistant in a soundproof booth, using a clinical audiometer Madsen OB822 equipped with THD39 headphones (Madsen Electronics, Denmark). The better ear hearing threshold level was defined as a pure-tone average of thresholds at 0.5, 1, 2 and 4 kHz. In accordance with the European Union recommendations, a person was defined as having hearing impairment if the hearing threshold level of the better ear was ≥21 dB [14].

Measures of postural balance

Balance was measured using the Good Balance force platform measurement system (Metitur, Jyväskylä, Finland) [6]. Vertical movement of the centre of pressure (COP) was measured during semitandem stance (heel of one foot positioned along side the big toe of the other foot) with gaze fixed at a point marked at the eye level at a distance of 2 m. During the balance testing, the participants were instructed to stand as still as possible in a well-balanced position. COP movement was recorded for 20 s. When all the measurement points were read, the medio-lateral (x) and anteroposterior (y) coordinates of the COP were calculated on the basis of these vertical force signals using the Good Balance software. To compensate for the possible influence of higher locations of the centre of mass among the taller subjects, the absolute COP measures were standardized for height [(COP variable/subject height) × 180]. The mean moment of velocity (VEL; mm²/s) was calculated as the mean of the areas covered by the movement of COP during each second of the test. Lower scores represent better balance. For the statistical analyses, participants were categorized into three equal groups according to the distribution of values. The cut-off values for tertiles were 32.91 mm²/s and 50.18 mm²/s (range 10.02–263.49 mm²/s). Nine persons were incapable of performing the test and were included in the poorest tertile. In this study, the participants in the poorest tertile were classified as having balance impairment.

Follow-up for falls

The follow-up data for falls during 12 months were gathered from 428 participants [6]. A fall was defined as unintentionally coming to rest on the ground, floor or other lower level for reasons other than unexpected overwhelming force [15]. The participants were requested to report their falls each day by marking in their calendars whether a fall had happened or...
Table 1. Baseline characteristics of fallers vs. non-fallers and participants with poorer VA (VA < 1.0) vs. participants with good vision (VA ≥ 1.0)

<table>
<thead>
<tr>
<th>Variable</th>
<th>VA &lt; 1.0 (n = 191)</th>
<th>VA ≥ 1.0 (n = 237)</th>
<th>Falls (n = 201)</th>
<th>Non-fallers (n = 227)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>69.1 ± 3.4</td>
<td>68.1 ± 3.3</td>
<td>68.6 ± 3.3</td>
<td>68.6 ± 3.4</td>
<td>0.96</td>
</tr>
<tr>
<td><strong>Number of chronic diseases</strong></td>
<td>2.1 ± 1.6</td>
<td>1.9 ± 1.3</td>
<td>2.0 ± 1.5</td>
<td>2.0 ± 1.4</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Number of prescribed medications</strong></td>
<td>2.0 ± 2.2</td>
<td>2.1 ± 2.2</td>
<td>2.1 ± 2.5</td>
<td>2.0 ± 1.8</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>MMSE (score)</strong></td>
<td>26.7 ± 2.3</td>
<td>27.3 ± 2.0</td>
<td>27.1 ± 2.2</td>
<td>27.0 ± 2.2</td>
<td>0.56</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>28.4 ± 5.4</td>
<td>27.7 ± 4.1</td>
<td>28.6 ± 4.8</td>
<td>27.5 ± 4.7</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Standing balance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best tertile</td>
<td>53 (28)</td>
<td>88 (37)</td>
<td>67 (33)</td>
<td>74 (33)</td>
<td></td>
</tr>
<tr>
<td>Middle tertile</td>
<td>62 (32)</td>
<td>79 (33)</td>
<td>141 (33)</td>
<td>82 (36)</td>
<td></td>
</tr>
<tr>
<td>Poorest tertile</td>
<td>76 (40)</td>
<td>70 (30)</td>
<td>146 (34)</td>
<td>71 (31)</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>Hearing impairment</strong></td>
<td>74 (39)</td>
<td>101 (43)</td>
<td>89 (44)</td>
<td>86 (38)</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td>9 (5)</td>
<td>13 (5)</td>
<td>9 (4)</td>
<td>13 (6)</td>
<td>0.56</td>
</tr>
<tr>
<td><strong>Cardiovascular disease</strong></td>
<td>101 (53)</td>
<td>133 (56)</td>
<td>112 (56)</td>
<td>122 (54)</td>
<td>0.69</td>
</tr>
</tbody>
</table>

*P-values were calculated using the adjusted Wald test.

J. Kulmala et al.

At the end of each month, the participants mailed the relevant calendar page to the research centre.

**Descriptive variables**

The presence of physician-diagnosed chronic conditions and the use of medications were self-reported and later confirmed in a clinical examination. The Mini-Mental State Examination (MMSE) was used to test cognitive capacity [16]. Participants’ weight was measured with a beam scale and height with a stadiometer. Body mass index (BMI) was calculated by dividing weight (kg) by height (m) squared.

**Statistical analysis**

Although the present sample consisted of twins, the sample was treated as a set of individuals by taking into account the interdependence between the sisters. Mean differences in age, cognitive function, number of chronic diseases, number of prescribed medications and BMI and the distribution of hearing and balance impairment, prevalence of diabetes and cardiovascular diseases within persons in two VA categories and among those who experienced at least one fall compared to non-fallers were tested with the Wald test adjusted for within-pair dependence.

To study the effects of visual loss and co-existing impairments on fall risk, the following five exclusive groups were formed on the basis of VA, balance and hearing: (1) participants with VA of 1.0 or over (the reference group); (2) impaired vision, but no other impairments; (3) co-existing vision and balance impairment; (4) co-existing vision and hearing impairment; (5) all three impairments (vision, hearing, balance).

The association between VA and co-existing sensory deficits and falls was assessed using the negative binomial regression model [17, 18]. The strength of the association was calculated with incidence rate ratios (IRRs). The negative binomial regression model takes into account that falls are non-independent observations, tend to be recurrent events and that one fall makes future falls more likely. With this approach, it is possible to enter the Poisson-distributed count variable for the number of falls in the models. IRRs are interpreted as the relative risk estimates. In addition, 95% confidence intervals were estimated. Age and interdependence between the twins were taken into account in all the regression models. The modelling was performed using STATA statistical software (Stata Corp., College Station, TX, USA). P-values of <0.05 were considered as statistically significant.

**Results**

The mean VA in our study group was 0.9 ± 0.3. A total of 191 persons (44%) had a VA below 1.0. Vision-impaired subjects were somewhat older than persons with good vision (69.1 vs. 68.1, P = 0.001) and had a lower MMSE score (mean 26.7 vs. 27.3, P = 0.003) than people with good vision. In addition, we found that the prevalence of impaired balance was higher among vision-impaired persons compared to those with good vision, although the difference was of borderline statistical significance (P = 0.053). There were no significant differences in the prevalence of chronic diseases, prescribed medications, BMI or the prevalence of hearing impairment between the VA groups (Table 1). Altogether, 75 (18%) participants had only vision impairment, 40 (9%) had co-existing vision and hearing impairment, 42 (10%) had co-existing vision and balance impairment and 34 (8%) participants had all three impairments.

Altogether, 227 participants reported no falls, while 201 participants reported a total of 440 falls within a mean follow-up time of 345 ± 39 days. The mean incidence of falls in our study group was 8.9 falls per 100 person-months. There were
Vision and falls

Figure 1. Percentages of persons with 0, 1, 2 and recurrent falls in groups formed on the basis of VA, balance and hearing ability.

Table 2. Risk of falls in 1-year follow-up among persons with vision loss and co-existing sensory impairments compared to persons with good vision

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of participants at baseline</th>
<th>No. of falls during the follow-up</th>
<th>IRR</th>
<th>P-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA ≥ 1.0</td>
<td>237</td>
<td>201</td>
<td>1.0</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>VA &lt; 1.0</td>
<td>75</td>
<td>63</td>
<td>1.5</td>
<td>0.39</td>
<td>0.6–4.2</td>
</tr>
<tr>
<td>VA &lt; 1.0 + balance impairment</td>
<td>42</td>
<td>34</td>
<td>2.7</td>
<td>0.073</td>
<td>0.9–8.0</td>
</tr>
<tr>
<td>VA &lt; 1.0 + hearing impairment</td>
<td>40</td>
<td>65</td>
<td>4.2</td>
<td>0.006</td>
<td>1.5–11.3</td>
</tr>
<tr>
<td>VA &lt; 1.0 + hearing impairment + balance impairment</td>
<td>34</td>
<td>77</td>
<td>29.4</td>
<td>&lt; 0.001</td>
<td>5.8–148.3</td>
</tr>
</tbody>
</table>

All analyses are adjusted for age and interdependence between the twins. VA = visual acuity.

Discussion

The main result obtained from this study was that poor vision accompanied with loss of hearing or balance increased the risk for falls. The risk increased further when poor vision was accompanied with loss of both hearing and balance. We are not aware of other prospective studies on the effects of objectively measured co-existing sensory and balance impairments on fall risk, although the predictive value of single impairments as a risk factor for falls has been shown. Previously, Tinetti et al. found falling incidence to increase significantly along with the number of predisposing factors, such as slow-timed chair stands, decreased arm strength, decreased vision and hearing and a high score for anxiety or depression score [19]. In an earlier retrospective study among persons aged 70 or older, those with co-existing self-reported vision and hearing impairment had a further increased risk for falls of 29.4 (95% CI 5.8–148.3).
hearing impairment were three times more likely to have fallen during the previous 12 months than persons without vision or hearing problems [10].

VA has an important role in balance control by providing the nervous system with continuously updated information regarding the position and movements of body segments in relation to each other and to the environment. Previous studies have shown that when people with normal vision stand with their eyes closed, postural sway increases markedly, indicating difficulty in balance control in the absence of visual feedback [20]. In addition, people with vision impairment have impaired functional balance more often than those with better vision [21]. However, in addition to vision, the ability to maintain an upright position depends on the interaction of multiple physiological systems, including vision, the vestibular system and proprioception. These balance control systems send signals to the central nervous system about head and body movements. The complex structure of the sensory input involved in maintaining an upright position and the interaction between vision and other sensory systems makes it possible for people with only one sensory impairment to compensate for the lack of information from that channel by using other sensory information available. This is supported by previous studies among people with blindness or deafness, where changes have been observed in the processing of information by the remaining sensory modalities [22, 23]. We propose that the increased impact of vision impairment on fall risk, when accompanied with other sensory or balance impairments, is due to lack of compensatory information about body posture and the environment from other sensory sources.

Previous studies indicate that about one-third of persons aged 65 years and older fall each year and half of this number fall repeatedly [24]. This is in line with our observations according to which a little less than half of the subjects reported at least one fall. Our study suggested that a regular ophthalmic examination and audiometric screening followed by appropriate treatment and rehabilitation, such as surgery, use of spectacles or a hearing aid could help prevent falls. In previous studies especially cataract surgery and visual correction have been shown to be effective in reducing fall rates in older people [25]. In addition, interventions aiming at improving balance have been found effective in preventing falls in older persons [26]. These studies have not specifically comprised individuals with vision and hearing impairment, but we imagine that training focused on improving awareness of postural control could be useful for them as well in terms of fall prevention. Furthermore, attention should be paid to the prevention and good treatment of diseases, such as diabetes and cardiovascular diseases, which affect sensory systems negatively [27, 28]. A multifactorial approach is likely the most effective method in reducing falls in older people, while some single methods also seem beneficial.

The strengths of this study include a relatively large number of participants, the use of standardized measures of vision, hearing and balance, and detailed follow-up data on falls. However, it should be noted that VA is not a static state. We measured the best-corrected VA with spectacles if needed, and thus it is possible that in some cases a fall may have occurred in the absence of spectacles, meaning that vision was worse at the time of the fall. In addition, we classified all participants with a VA of <1.0 as having visual impairment, according to the standard definition of normal VA. In this study, the participants were relatively young and healthy, and the proportion of persons with severe vision impairment was small. Therefore, the current study may not capture the impact of more severe vision loss on fall risk. Further, there are no data available about possible surgery or other eye-related events, which may have affected VA during the follow-up. In addition, despite the clear increase in fall risk among persons with multiple impairments, the confidence intervals were relatively wide. This was mainly the consequence of the limited number of participants in the poorest categories. It should be noted that this study consisted only of women and the age range was quite narrow. Therefore, to confirm the results of our study, prospective studies with more heterogeneous study populations are warranted.

Our study indicated that co-existing sensory and balance deficits are powerful predictors of falls in older women. We propose that the presence of other sensory impairments in addition to visual loss prevents older people from receiving compensatory information about body position and the environment, thus predisposing them to falling.

Key points

- Poor vision increased the risk for falls particularly when it was accompanied with loss of hearing or balance and, even further, when accompanied with loss of both hearing and balance.
- Co-existing sensory deficits showed additional effect on fall risk.

Acknowledgements

We are indebted to all the participants for their commitment to the study. Some of the results were presented as a poster at the Gerontological Society of America 60th Annual Scientific Meeting, 16–20 November 2007 in San Francisco, CA, USA.

Conflicts of interest

There are no conflicts of interest.

Funding

This study was financially supported by the University of Jyväskylä and Juho Vainio Foundation grants. J.K. is supported by the Academy of Finland Centre of Excellence in Complex Disease Genetics. S.P. was supported by the
Intramural Research Program of the NIH, National Institute of Aging. The mentioned organizations have played a role neither in the design, execution, analysis and interpretation of data, nor in the writing of the studies.

References


Received 18 December 2007; accepted in revised form 26 June 2008