Subjective vision and hearing impairment and falls among community-dwelling adults: a prospective study in the Survey of Health, Ageing and Retirement in Europe (SHARE)

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Abstract

Purpose: To investigate the association between vision and hearing impairment and falls in community-dwelling adults aged ≥ 50 years.

Methods: Prospective study on 50,986 participants assessed in Wave 6 and 7 of the Survey of Health, Ageing and Retirement in Europe. At baseline, we recorded socio-demographic data, clinical factors and self-reported vision and hearing impairment. We classified participants as having good vision and hearing, impaired vision, impaired hearing or impaired vision and hearing. We recorded falls in the six months prior to the baseline and 2-year follow-up interviews. The cross-sectional and longitudinal associations between vision and hearing impairment categories and falls were analysed by binary logistic regression models; odds ratios (OR) and 95% confidence intervals (CI) were calculated. All analyses were adjusted for socio-demographic and clinical factors.

Results: Mean age was 67.1 years (range 50-102). At baseline, participants with impaired vision, impaired hearing, and impaired vision and hearing had an increased falls risk (OR (95% CI)) of 1.34 (1.22 – 1.49), 1.34 (1.20 – 1.50) and 1.67 (1.50 – 1.87), respectively, compared to those with good vision and hearing (all $p < 0.001$). At follow-up, participants with impaired vision, without or with impaired hearing, had an increased falls risk of 1.19 (1.08 – 1.31) and 1.33 (1.20 – 1.49), respectively, compared to those with good vision and hearing (both $p < 0.001$); hearing impairment was longitudinally associated with falls in middle-aged women.

Conclusion: Vision impairment was cross-sectionally and longitudinally associated with an increased falls risk. This risk was highest in adults with dual sensory impairment.

Keywords: falls; vision disorders; eye diseases; presbycusis; dual sensory impairment; population-based prospective study.

Declarations

Acknowledgements: This paper uses data from SHARE Waves 6 and 7 (DOIs: 10.6103/SHARE.w6.710, 10.6103/SHARE.w7.711), see Börsch-Supan et al. (2013) for methodological details [Borsch-Supan A, Brandt M, Hunkler C, et al. SHARE Central Coordination Team. Data Resource Profile: the Survey of Health, Ageing and Retirement in Europe (SHARE). Int J Epidemiol 2013;42:992–1001].

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Key summary points

Aim To investigate the relationship between self-reported vision and hearing impairment and falls risk in community-dwelling adults aged ≥ 50 years in the cross-national Survey of Health, Ageing and Retirement in Europe (SHARE).

Findings Self-reported vision impairment, versus no impairment, was cross-sectionally and longitudinally associated with an increased falls risk in adults, independent of age, sex, self-rated health, comorbidities and medications. The risk was highest when vision and hearing impairment coincided.

Message Simple questions on self-reported sensory impairment can be used to assess the risk of falls in adults.

Introduction

Vision impairment [1, 2], hearing impairment [1, 3, 4] and falls [5-9] are common among adults, with their prevalence increasing with age. About one in three older adults fall each year [5] and 5 to 10% of falls leads to a major injury [6, 7, 9]. In this way, falls are a serious public health issue, leading to increased morbidity, mortality, institutionalization and health care cost [8, 9]. Both injurious and non-injurious falls can result in fear of falling, reduced quality of life, loss of confidence and independence [9]. Therefore, identifying potentially modifiable and common risk factors for falls is crucial.

Vision impairment has been associated with an increased falls risk [5, 9, 10]. However, previous reports examining the association between objective measures of vision components and falls risk have yielded conflicting results [5, 9-15] partly because vision includes many components, such as visual acuity, visual field, depth perception and contrast sensitivity [11-15]. In the Blue Mountains Eye Study, poor visual acuity was associated with an increased falls risk among adults aged 49 years and older [13]; however, this association was not linear and might have been mediated by reduced depth perception [9, 11]. Indeed, reduced depth perception has been prospectively associated with recurrent falls [9, 12]. In the Blue Mountains Eye Study and in the Los Angeles Latino Eye Study, visual field impairments were associated with an increased falls risk [13, 14]; yet, diseases known to affect the visual field and acuity, such as macular degeneration, were not [13]. Moreover, a few studies suggested that contrast sensitivity may be more important than visual acuity in predicting falls [11]. On the other hand, self-reported vision – as assessed by simple, brief, inexpensive questions – could be a global measure of all vision components and may predict falls risk beyond visual acuity [15]. Yet, few prospective studies have investigated the association between self-reported vision and falls risk in adults [16-20]. Hearing impairment has also been associated with an increased falls risk [10]. Auditory inputs contribute to spatial awareness [21]; in contrast, hearing impairment has been correlated with greater postural instability and falls [21-23]. Adults with hearing impairment may invest more attentional and cognitive resources into hearing, leaving fewer resources available for balance control [22]. In addition, hearing impairment often coincides with vestibular impairment [22]. Yet, the association between hearing and falls is still controversial [10, 18-30]. Moreover, few studies on this association were longitudinal [18-20, 23, 25, 26, 28-30] or examined self-reported hearing [18-20, 27, 29]. Furthermore, few studies have examined the effect of dual sensory impairment – vision and hearing impairment – on falls risk [28-30]. Yet, dual sensory impairment will become more common with the ageing of the population worldwide [1-4]. At present, dual sensory impairment affects about 8% of community-dwelling Americans aged 70 years or older [31]. Moreover, with an increasing trend towards virtual consultations, these impairments will be more frequently assessed by self-report in the future.

The aim of this study was to examine whether visual and hearing impairment, either alone or together, were cross-sectionally and longitudinally associated with risk of falls in community-dwelling men and women aged 50 years and older, independent of self-rated health, co-morbidities and medications.

Methods

Study design and population

The Survey of Health, Ageing and Retirement in Europe (SHARE) is a multidisciplinary and cross-national panel database of microdata on health, socio-economic status and social and family networks of individuals aged 50 years and older in European countries and Israel [32]. Started in 2004, SHARE comprises eight biennial survey waves. We conducted a prospective study using data from Wave 6 and 7 of SHARE [33, 34].

At baseline (Wave 6), 68,186 participants had a main interview. We excluded those younger than 50 years or of unknown age (n = 1,015), those resident in a nursing home or unknown (n = 772) and those with missing data on either vision or hearing function (n = 206), or use of hearing aids or glasses (n = 5), or falls at baseline (n = 15) or other co-variates (n = 93). At follow-up (Wave 7), we further excluded 15,094 participants who did not have a main interview (n = 14,779) or data on falls (n = 315).

Therefore, this study includes 50,986 participants, aged 50 years or older at baseline (Wave 6), who were followed-up (Wave 7) and had complete data of interest. These participants were residents from 18 countries (Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Israel, Italy, Luxembourg, Poland, Portugal, Slovenia, Spain, Sweden and Switzerland). Figure 1 details the Flow-chart of study inclusion criteria.

Those 15,094 participants who were lost to follow-up between Wave 6 and 7 were older, more likely to be men, and report falls and vision impairment, with or without hearing impairment, at baseline, compared to those 50,986 participants who were included in our study (Supplementary Table 1).

Demographic and clinical characteristics

Baseline interviews (Wave 6) were carried out from January to November 2015 and the following variables were collected: age, sex, self-rated health, self-reported co-morbidities, medications and falls.

Self-rated health was assessed by asking the participants: "*Would you say your health is …*"*;* options were: "*excellent*", "*very good*", "*good*", "*fair*" or "*poor*". We dichotomised self-rated health as good ("*excellent*" or "*very good*" or "*good*") versus poor ("*fair*" or "*poor*").

Co-morbidities were assessed by asking the participants: "*Has a doctor ever told you that you had/ do you currently have any of the conditions on this card?*"; a show-card with multiple non-mutually exclusive options was presented to the participants. We focussed on these co-morbidities: heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder, any arthritis (including rheumatoid arthritis and osteoarthritis / other rheumatism).

Similarly, medications were assessed by asking: "*Do you currently take drugs, at least once a week, for problems mentioned on this card?*" and a list was shown. Based on previous literature [9, 10], we selected these medications: anti-hypertensives, drugs for pain (including drugs for joint pain and those for other pain) and psychotropic drugs (including drugs for sleep problems and those for anxiety or depression).

Falls at baseline were assessed by asking the participants: "*For the past six months at least, have you been bothered by any of the health conditions on this card?*"; options included: "*falling down*", "*fear of falling down*", "*dizziness, faints or blackouts",* "*fatigue*" or "*none*" (participants could choose more than one option). Falls at baseline were dichotomized as "no" (no falls) versus "yes" (one or more falls).

Vision and hearing impairment

Distant and close vision, respectively, were assessed by asking the participants: "*How good is your eyesight for seeing things at a distance, like recognising a friend across the street – wearing glasses or contact lenses if needed? Would you say it is...*" and "*How good is your eyesight for seeing things up close, like reading ordinary newspaper print – wearing glasses or contact lenses if needed? Would you say it is...*" options included: "*excellent*", "*very good*", "*good*", "*fair*" or "*poor*". We dichotomised vision as good (if both distant and close vision were "*excellent*" or "*very good*" or "*good*") versus impaired (if distant and or close vision were "*fair*" or "*poor*").

Similarly, hearing was assessed by asking the participants: "*Is your hearing [using a hearing aid as usual]...*" options were: "*excellent*", "*very good*", "*good*", "*fair*" or "*poor*". We dichotomised hearing as good ("*excellent*" or "*very good*" or "*good*") versus impaired ("*fair*" or "*poor*").

Finally, we classified the participants into the following four categories: 1) good vision and hearing, 2) impaired vision only, 3) impaired hearing only and 4) impaired vision and hearing (dual sensory impairment). Moreover, we recorded whether participants usually wore glasses (or contact lenses) or hearing aids.

Falls

Follow-up interviews (Wave 7) were conducted from February 2017 to January 2019 and the participants were again asked the question: "*For the past six months at least, have you been bothered by any of the health conditions on this card?*"; options included: "*falling down*". Our outcome of falls at follow-up was dichotomized as "no" (no falls) versus "yes" (one or more falls).

Statistical analyses

All analyses were performed in the total population and in men and women, separately.

We reported the baseline characteristics of the study population by sex and across categories of vision and hearing impairment, respectively. We tested for differences in baseline characteristics using Pearson's chi-square test for categorical variables, t-test or analysis of variance (ANOVA) for age (used as a continuous variable), as appropriate.

Binary logistic regression models were used to assess the cross-sectional and longitudinal association between visual and hearing impairment categories at baseline (determinant) and falls at follow-up (outcome). The "good vision and hearing" category was the reference. We performed our cross-sectional and longitudinal analyses in two and three steps, respectively. First, we adjusted our analyses for age and sex (Model 1) and then further added self-rated health, co-morbidities, medications, use of glasses and use of hearing aids (Model 2); in longitudinal analyses, we finally further adjusted for falls at baseline, as a marker of frailty (Model 3). In our Models of adjustment, we used age as a continuous variable. We separately entered each co-morbidity and medication variable in Model 2.

We repeated the cross-sectional and longitudinal analyses in the sample of participants aged 80 years and older. Further longitudinal analyses were performed by stratifying the participants into two age groups: aged 50 to 64 years versus aged 65 years and older. Further analyses were performed after excluding participants who reported falls at baseline or those who were followed up after 2017. All analyses were performed using SPSS 25.

Ethics

SHARE obtained institutional review board approval by the University of Mannheim (Waves 1 to 4) and the Max Planck Society (Wave 4 and the continuation of the project) [32-34].

Results

Characteristics at baseline

In our study population, mean age was 67.1 (standard deviation (SD) 9.5; range 50 to 102) years and 28,868 (56.6%) participants were women. A total of 11,290 (22.1%) participants reported vision impairment and 9,782 (19.2%) reported hearing impairment. When combining data, 33,767 (66.2%) participants reported good vision and hearing, 7,437 (14.6%) impaired vision only, 5,929 (11.6%) impaired hearing only and 3,853 (7.6%) impaired vision and hearing (Table 1). Women were more likely to report vision impairment, while men hearing impairment (both $p < 0.001$). Supplementary Table 2 details the characteristics of participants aged 80 years and older at baseline.

Participants with good vision and hearing were the youngest and least likely to report poor health, comorbidities and medications; in contrast, those with impaired vision and hearing were the oldest and most likely to report poor health, co-morbidities and medications (all $p < 0.001$, Table 2). The frequencies of poor health, co-morbidities and medications were intermediate among participants with impaired vision only or impaired hearing only. Similar findings were observed in both sexes (Supplementary Table 3 for men and 4 for women).

Most participants wore glasses (n = 43,251, 84.8%); a minority used hearing aids (n = 3,162, 6.2%). In particular, hearing aids were used by 1,133 (11.6%) participants reporting hearing impairment.

Cross-sectional analyses

At the baseline interview, 3,472 (6.8%) participants – in particular, 1,006 (4.5%) men, 2,466 (8.5%) women, 932 (15.8%) of those aged 80 years and older – reported falls.

In age- and sex-adjusted analyses (Model 1), participants with impaired vision only, impaired hearing only or impaired vision and hearing, respectively, had an increased falls risk compared to those with good vision and hearing (Table 3). After full adjustment (Model 3), participants with impaired vision only, impaired hearing only and impaired vision and hearing, respectively, had an increased risk of falls of 1.34 (1.22 – 1.49), 1.34 (1.20 – 1.50) and 1.67 (1.50 – 1.87), compared to those with good vision and hearing (all $p < 0.001$, Table 3). These findings were consistent in both sexes (Table 3).

Among participants aged 80 years and older, those with dual sensory impairment had an increased risk of falls of 1.40 (1.15 – 1.71), compared to those with good vision and hearing, after full adjustment (Supplementary Table 5). This association was consistent in women aged 80 years and older.

Longitudinal analyses

Mean time interval between baseline and follow-up interview was 24.5 (SD 3.6) months. At the follow-up interview, 4,214 (8.3%) participants – in particular, 1,351 (6.1%) men 2,863 (9.9%) women, 1,136 (19.2%) of those aged 80 years and older at baseline – reported falls.

Covariates and falls risk

In our total study population, these covariates were longitudinally associated with increased falls risk, after full adjustment (Model 3): older age, female sex (versus male), poor self-rated health (versus good), falls at baseline (versus no falls), ischemic heart disease, stroke, diabetes, chronic lung disease, Parkinson's disease, hip fracture, other fracture, affective or emotional disorder, any arthritis, use of drugs for pain (versus no use), use of psychotropic drugs (versus no use) and use of glasses (versus no use) (Supplementary Table 6). Hearing aids use was not prospectively associated with falls risk.

Vision and hearing impairment and falls risk

In age- and sex-adjusted analyses (Model 1), we observed longitudinal associations between vision and or hearing impairment and risk of falls. Participants with impaired vision only, impaired hearing only and impaired vision and hearing had an increased risk (OR (95% CI)) of falls of 1.58 (1.45 – 1.73), 1.39 (1.26 – 1.54) and 2.30 (2.08 – 2.53), respectively, compared to those with good vision and hearing (Table 4).

Impaired hearing only was associated with an increased falls risk, independent of age, sex, self-rated health, co-morbidities and medications (Model 2), but this association lost statistical significance after further adjustment for baseline falls (Model 3, Table 4).

After full adjustment (Model 3), participants with impaired vision only and those with impaired vision and hearing had an increased risk of falls of 1.19 (1.08 – 1.31) and 1.33 (1.20 – 1.49), respectively, compared to those with good vision and hearing (Table 4). Similar findings were observed in both sexes.

After exclusion of participants reporting falls at baseline, impaired vision only, impaired hearing only and dual sensory impairment were all associated with an increased falls risk (Supplementary Table 7).

Age-stratified results

Supplementary Table 8 presents the fully-adjusted age-stratified longitudinal associations between vision and or hearing impairments and risk of falls. Among participants aged 50 to 64 years, impaired vision only, impaired hearing only and impaired vision and hearing were all

associated with an increased falls risk, compared to good vision and hearing (Supplementary Table 8). All these findings were consistent among women aged 50 to 64 years. Among men aged 50 to 64 years, dual sensory impairment was associated with an increased falls risk.

Among participants aged 65 years and older, impaired vision, with or without impaired hearing, was associated with an increased risk of falls, compared to good vision and hearing; in contrast, no association was found between impaired hearing only and falls (Supplementary Table 8).

Among participants aged 80 years and older, no longitudinal association between any sensory impairment and falls risk was observed, after full adjustment (Supplementary Table 9).

Discussion

In this large population-based cross-European study, vision impairment, with or without hearing impairment, was cross-sectionally and longitudinally associated with an increased risk of falls in community-dwelling adults aged 50 years and older. The risk of falls was highest when vision impairment coincided with hearing impairment. In contrast, hearing impairment, without vision impairment, was cross-sectionally but not longitudinally associated with an increased falls risk. All these associations were independent of age, sex, self-rated health, co-morbidities, medications and previous falls and consistent in both middle-aged and older adults.

There is a vast literature on vision and falls [5, 9-20]. However, few population-based studies have explored the association between self-reported vision impairment and falls risk [15-20]. Of these, a few only assessed cross-sectional associations [15, 16]; others investigated longitudinal associations, with conflicting results [17-20]. Among older community-dwelling Chinese women, self-reported vision was correlated with future indoor injurious falls, but not independently of covariates [17]. Among Australian older men and women, self-reported vision impairment, was prospectively associated with increased falls risk [18]. In a Brazilian study, self-reported vision impairment was prospectively associated with falls and recurrent falls in community-dwelling older adults, independently of covariates, while self-reported hearing impairment was not [19].

There is growing literature on hearing impairment and falls. Hearing impairment was objectively measured in most studies [23-26, 28, 30], self-reported in a few [17-20, 27] or both measured and self-reported in another [29]. Among Chinese older women, self-reported hearing impairment was not prospectively associated with indoor injurious falls, after adjustment for covariates [17]. Moreover, self-reported hearing impairment was longitudinally associated with an increased falls risk among adults of population-based studies from Australia and the Netherlands [18, 20], but not from Brazil [19]. In NHANES, hearing loss was independently associated with falls over the preceding 12 months, among adults aged 40 to 69 years [24]. In the Health ABC study, moderate-or-greater hearing impairment was longitudinally associated with incident frailty and falls among high-functioning, community-dwelling older adults; hearing aid use did not modify the risk of frailty or falls [25]. In the Finnish Twin Study on Aging, older women with hearing impairment, had higher falls risk at 1-year follow-up, compared to those with good hearing; this was partially explained by worse postural control in those with hearing impairment [23]. In the Blue Mountains Eye Study, objectively measured hearing loss was not associated with greater falls incidence, while self-perceived hearing impairment was [29]. Other studies did not show any association of hearing impairment with falls [26, 27]. Hearing sensitivity was not prospectively associated with falls risk among older women in the Study of Osteoporotic Fractures [26]. In the National Health Interview Survey, self-reported hearing impairment was not independently associated with nonfatal fall-related injury, among community-dwelling Americans aged 18 years and older [27].

Few prospective studies assessed the effect of dual sensory impairment on falls risk [28-30]. In the Finnish Twin Study on Aging, co-existing vision and hearing impairment were associated with greater risk for falls among older women, compared to vision impairment alone; co-existing sensory deficits showed an additional effect on fall risk [28]. In the Blue Mountains Eye Study, co-existing vision and hearing impairment was correlated with a 2-fold increased risk of two or more falls over a 5-year follow-up [29]. In contrast, a multicentre Nordic hospital-based prospective study found that combined vision and hearing impairment was not independently associated with falls over three months, among adults aged 75 years and older [30].

The above-described discrepancies among studies may be related to differences in the age-, sex-and ethnic- composition of the study population [1-4, 18], study design (cross-sectional or longitudinal), setting (population-based or hospital based) and variability in the measurement and classification of vision and hearing impairment (objective measures or self-report; different threshold for defining impairment). In particular, studies in older [17, 19, 26, 30] or frailer, hospitalized [30] populations may fail to show independent associations between sensory impairment and falls, due to more competing risk factors for falls in these populations. The relative importance of sensory impairment as a falls risk factor may be greater in middle-aged than in older adults and similarly, in community-dwelling adults than in frail, hospitalised adults. Consistent with this, in our study, isolated hearing impairment was independently associated with an increased falls risk in adults aged 50 to 64 years but not in those aged 65 years and older. Globally, our study population was younger than those of other studies [17, 19, 26, 30]. Moreover, a few previous studies with nonsignificant findings were relatively small and possibly lacked statistical power [17, 19, 30]. Furthermore, the relationships between sensory impairment and falls risk may be graded [11, 24]; if this holds true, the finding of associations and their strength may vary according to the definition and measurement of sensory impairment.

Furthermore, our study examined both cross-sectional and longitudinal associations; the strength of associations became attenuated in longitudinal analyses. During the 2-year follow-up, many participants with good vision and hearing at baseline may have become sensory impaired; in contrast, most of those with sensory impairment at baseline may not have recovered their function. In this way, the contrast between participants with and without sensory impairment at baseline may reduce longitudinally; moreover, competing risk factors for falls become more prevalent as the study population ages. As a consequence, the cumulative incidence of falls throughout the 2-year follow-up may differ more than that in the six months preceding the follow-up interview. The duration of follow-up may influence the longitudinal associations between sensory impairment and falls risk; the longer the follow-up, the more attenuated the associations. This could contribute to discrepancies across longitudinal studies with follow-up of different durations [17-20, 23, 25, 26, 28, 29].

Age, sex and ethnicity may influence the prevalence of sensory impairment [1-4], the rate of falls [10] and possibly the relationship between sensory impairment and falls and contribute to heterogeneity of findings among studies.

In our population-based study of middle-aged and older adults, the rate of falls was about 7 to 8% in the six months prior to the baseline and follow-up interview, respectively. These were lower compared to falls rates of about 25 to 27% in the previous twelve months, in previous studies of community-dwelling middle-aged and older adults [13-15]. This might be due to healthy respondent bias or cohort effect (contemporary adults may be healthier than adults of the eighties [5]). In line with previous literature, older age and female sex were falls risk factors, independently of co-morbidities, in our study [10].

The prevalence of self-reported vision impairment (22.1%) in our European population-based study was intermediate between those of reports from the U.S. and UK [16, 35], and that of a Chinese study [36]. Our prevalence of hearing impairment (19.2%) was lower than that of a sample of adults over 60 years in the English Longitudinal Study of Ageing [37]. In line with previous reports, women in our study were more likely to report vision impairment, while men hearing impairment [1-4, 18]. In our study, hearing aids were used only by 11.6% participants reporting impaired hearing; similarly, studies from the U.S. reported underuse of hearing aids [3].

In our study, use of glasses was prospectively associated with increased falls risk, independently of vision impairment. Of note, a few randomized-controlled trials showed that comprehensive vision and eye assessment, with appropriate treatment and provision of glasses if needed, did not reduce [38], or could even increase [39, 40], the falls risk in older adults. Older adults may need a considerable period of time to adjust to new eyeglasses and could be at greater risk of falling during this time [39]. We could not find any association between use of hearing aids and falls; however, given the low frequency of hearing aids use, our study might have been underpowered.

Different, non-mutually exclusive explanations for the association between vision and hearing loss and falls have been proposed.

First, vision and hearing may be needed for mobility. Vision contributes to the maintenance of balance and control of postural sway when standing [11, 41]. Indeed, sway increases with eyes closed compared with eyes open; sway is a strong risk factor for future falls [11, 41, 42]. Various components of vision are crucial for mobility. Depth perception, i.e. the ability to accurately judge distances and perceive spatial relationship, is required for navigating through obstacles in the environment [9, 12]. Contrast sensitivity is important in detecting indoor and outdoor hazards, such as steps, curbs, pavement cracks or clutter [12]. Lower visual field may be needed to detect objects in the environment that could be tripped over when walking [12]. Visual field – both central and peripheral – is important to assess ground surfaces and moving pedestrians or vehicles [14]. Similarly, hearing contributes to spatial awareness and postural stability [21, 22].

Second, vision and hearing deficits may increase the cognitive load; adults with these deficits may invest more cognitive resources in vision and hearing and less in mobility tasks requiring attention [21, 22]. The cognitive load may be greater in outdoor environments, due to more

unpredictable hazards, such as other pedestrians or traffic, compared to indoor environments. Thus, adults with sensory impairments may have greater difficulty outdoors than indoors.

Third, shared pathological pathways may underlie both vision and hearing impairment and falls; for example, cardiovascular risk factors and diseases – such as diabetes mellitus – are common risk factors for both sensory impairments and falls [2, 3, 10]. Yet, in our study, the association between vision impairment and falls risk remained significant, though attenuated, after adjustment for comorbidities. Likewise, ageing is associated with both sensory deficits and falls [1-5]; yet, the correlation between sensory impairment and falls in our study was independent of age and consistent among participants aged 50 to 64 years. Moreover, hearing and vestibular impairment frequently coincide; the association of hearing impairment with increased falls risk may be partly explained by concomitant vestibular dysfunction; yet, hearing per se may affect balance and falls risk [21, 22].

Finally, vision and hearing impairment may be causally linked to fear of falling [43], social isolation, depression [36], frailty [25, 35, 37] and cognitive decline [44]; longitudinal associations between sensory impairment and the latter have been shown by observational studies; causality has not been proven yet.

The findings of this study have clinical implications. Some causes of visual and hearing impairment in older adults may be preventable or treatable; however, it is unknown whether treating them could reduce falls risk in adults. Randomized trials from England found that first eye cataract surgery reduced the risk of falls and fractures in older women [45], while second eye cataract surgery did not [46]. Moreover, a large retrospective cohort study from Australia reported an increased risk of injurious falls after first- and second-eye cataract surgery [47].

Healthy lifestyle behaviours – use of hats and sunglasses for UV protection and smoking cessation – may promote eye health [48]. Similarly, limiting exposure to harmful noise – in in the workplace and during leisure – may reduce noise-induced hearing loss [3]. It is unclear whether targeting cardiovascular risk factor and diseases may have beneficial effects on hearing; although a correlation between diseases such as diabetes and hearing loss is established, causality is not established [3].

Furthermore, our study supports the use of simple questions on self-reported sensory impairment to accurately assess the falls risk of community-dwelling adults. This is relevant for large scale screening and remote consultations.

Major strengths of our study are the large multinational sample size, the inclusion of both men and women of a wide age range, the cross-sectional and longitudinal design, the standardized methods for data collection and the adjustment for many co-variates. In particular, we included and specifically reported on adults aged 50 to 64 years, while many previous studies only focused on older adults [16, 19, 25, 30]. Indeed, we showed that vision and dual sensory impairment were longitudinally associated with falls also among middle-aged adults. Moreover, by performing longitudinal analyses, we could show that vision and hearing impairment preceded the falls (temporality of association). By adjusting for many covariates, we showed that most associations between sensory impairment and falls became attenuated but

remained significant; this implies that these associations are partly mediated by concomitant co-morbidities and medications yet persist beyond these.

Our study has certain limitations. First, causality cannot be inferred given the observational nature of this study; we cannot determine the mechanistic pathways through which vision and hearing impairment are associated with falls risk. Second, vision and hearing impairment were self-reported; objective measures were not available. Yet, self-reported hearing is an accurate measure [49] and self-reported vision may be more comprehensive than objective measures of separate vision components. Moreover, screening for sensory impairment using simple questions is brief, inexpensive and reproducible in large scale studies, mass screening in the community or remote consultations. Third, falls were retrospectively self-reported; falls, especially non-injurious falls, could be underreported. However, screening for falls by using a single question is less costly and more applicable to large populations than falls diaries. Although the SHARE questionnaire does not include a definition of "*falling down*", "*falling down*" was separately included among a list of physical health issues; based on this and on checking the translations of the questionnaire, we deem it unlikely that participants may have reported falls due to external forces (accidents, violence) or separate health issues (syncope and seizures). Moreover, the SHARE questionnaire does not distinguish outdoor and indoor falls or injurious and non-injurious falls. As a result, we could not explore whether sensory impairments may be greater risk factors for outdoor falls, compared to indoor falls. Nor could we explore whether sensory impairments may affect the risk of injury, following falls [11], maybe by reducing self-protection abilities. Fourth, we cannot exclude residual confounding; for instance, both hearing impairment and falls may be correlated with vestibular impairment. Fifth, we cannot exclude a healthy respondent bias as suggested by the lower rates of falls in our study; given this and the relatively small sample of participants aged 80 years and older, our study might lack statistical power to detect longitudinal associations between sensory impairment and falls risk in the oldest old. Sixth, those participants who were lost to follow-up, compared to those included in the analyses, were older, with a greater burden of sensory impairment, co-morbidities and previous falls and likely at greater falls risk; as a result, our associations might have been attenuated. Finally, our study included only community-dwelling adults; this may limit the generalizability of our findings to institutionalized populations, who have different falls risk profiles compared to those in the community [10, 50].

In this large cross-European study of community-dwelling adults, vision and dual sensory impairment were longitudinally associated with an increased falls risk, independent of age, sex, subjective health, co-morbidities and previous falls. Hearing impairment, without vision impairment, was longitudinally associated with an increased falls risk among women aged 50 to 64 years. Simple questions on self-reported sensory impairment can be used to assess the falls risk in adults. This is relevant for large scale screening of populations and useful for the increasing need of virtual consultations.

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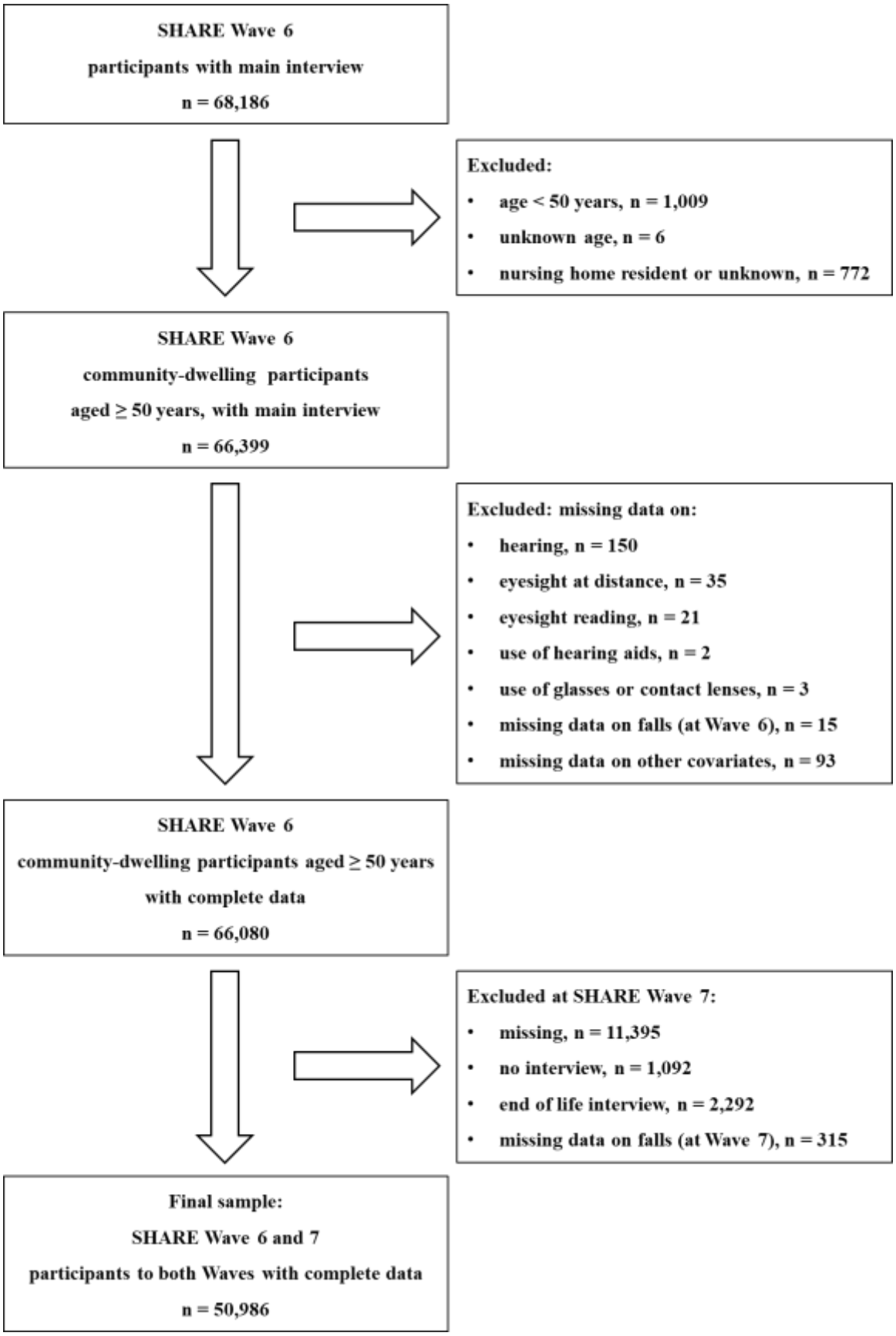
Figure 1 Flow-chart of study inclusion of participants



Abbreviations: SHARE: Survey of Health, Ageing and Retirement in Europe; n: number.

Table 1 Characteristics of total study population at baseline and stratified by sex

	All (n = 50,986)	Men (n = 22,118)	Women (n = 28,868)	P value
Age (years), mean (SD)	67.1 (9.5)	67.2 (9.1)	67.0 (9.7)	0.005
Vision and hearing categories, n (%):				
Good vision and hearing	33,767 (66.2)	14,557 (65.8)	19,210 (66.5)	<
Impaired vision only	7,437 (14.6)	2,670 (12.1)	4,767 (16.5)	0.001
Impaired hearing only	5,929 (11.6)	3,260 (14.7)	2,669 (9.2)	
Impaired vision and hearing	3,853 (7.6)	1,631 (7.4)	2,222 (7.7)	
Self-rated health, n (%):				
Good	31,492 (61.8)	14,213 (64.3)	17,279 (59.9)	<
Poor	19,494 (38.2)	7,905 (35.7)	11,589 (40.1)	0.001
Co-morbidities, n (%):				
Heart attack	5,679 (11.1)	3,010 (13.6)	2,669 (9.2)	< 0.001
Hypertension	21,357 (41.9)	9,194 (41.6)	12,163 (42.1)	0.200
High cholesterol	12,710 (24.9)	5,225 (23.6)	7,485 (25.9)	< 0.001
Stroke	1,718 (3.4)	921 (4.2)	797 (2.8)	< 0.001
Diabetes	6,877 (13.5)	3,302 (14.9)	3,575 (12.4)	< 0.001
Chronic lung disease	3,092 (6.1)	1,447 (6.5)	1,645 (5.7)	< 0.001
Cancer	2,157 (4.2)	951 (4.3)	1,206 (4.2)	0.497
Parkinson's disease	387 (0.8)	197 (0.9)	190 (0.7)	0.003
Cataracts	4,107 (8.1)	1,493 (6.8)	2,614 (9.1)	< 0.001
Hip fracture	817 (1.6)	300 (1.4)	517 (1.8)	< 0.001
Other fracture	2,174 (4.3)	856 (3.9)	1,318 (4.6)	< 0.001

Cognitive decline	765 (1.5)	306 (1.4)	459 (1.6)	0.057
Affective / emotional	3,343 (6.6)	935 (4.2)	2,408 (8.3)	< 0.001
Any arthritis	12,676 (24.9)	3,794 (17.2)	8,882 (30.8)	< 0.001
Drugs, n (%)				
Anti-hypertensives	22,998 (45.1)	10,025 (45.3)	12,973 (44.9)	0.385
Drugs for pain	13,056 (25.6)	4,187 (18.9)	8,869 (30.7)	< 0.001
Psychotropic drugs	6,353 (12.5)	1,744 (7.9)	4,609 (16.0)	< 0.001
Glasses, n (%)	43,251 (84.8)	18,334 (82.9)	24,917 (86.3)	< 0.001
Hearing aids, n (%)	3,162 (6.2)	1,694 (7.7)	1,468 (5.1)	< 0.001
Falls at baseline, n (%)	3,472 (6.8)	1,006 (4.5)	2,466 (8.5)	< 0.001

Abbreviation: n: number. P-values were computed by Pearson's chi-square for categorical variables and by t-test for the continuous variable age.

Table 2 Characteristics of study population at baseline stratified by vision and hearing impairment

	All (n = 50,986)	Good vision and hearing (n = 33,767)	Impaired vision only (n = 7,437)	Impaired hearing only (n = 5,929)	Impaired vision and hearing (n = 3,853)	P value
Age (years), mean (SD)	67.1 (9.5)	65.7 (8.9)	67.4 (9.8)	70.3 (9.4)	73.5 (10.2)	< 0.001
Women, n (%)	28,868 (56.6)	19,210 (56.9)	4,767 (64.1)	2,669 (45.0)	2,222 (57.7)	< 0.001
Self-rated health, n (%):						
Good	31,492 (61.8)	23,988 (71.0)	3,604 (48.5)	2,968 (50.1)	932 (24.2)	< 0.001
Poor	19,494 (38.2)	9,779 (29.0)	3,833 (51.5)	2,961 (49.9)	2,921 (75.8)	
Co-morbidities, n (%):						
Heart attack	5,679 (11.1)	2,981 (8.8)	954 (12.8)	935 (15.8)	809 (21.0)	< 0.001
Hypertension	21,357 (41.9)	13,113 (38.8)	3,288 (44.2)	2,838 (47.9)	2,118 (55.0)	< 0.001
High cholesterol	12,710 (24.9)	7,818 (23.2)	1,972 (26.5)	1,684 (28.4)	1,236 (32.1)	< 0.001
Stroke	1,718 (3.4)	875 (2.6)	313 (4.2)	246 (4.1)	284 (7.4)	< 0.001
Diabetes	6,877 (13.5)	3,939 (11.7)	1,162 (15.6)	945 (15.9)	831 (21.6)	< 0.001
Chronic lung disease	3,092 (6.1)	1,670 (4.9)	532 (7.2)	478 (8.1)	412 (10.7)	< 0.001
Cancer	2,157 (4.2)	1,261 (3.7)	351 (4.7)	330 (5.6)	215 (5.6)	< 0.001
Parkinson’s disease	387 (0.8)	171 (0.5)	72 (1.0)	60 (1.0)	84 (2.2)	< 0.001
Cataracts	4,107 (8.1)	1,849 (5.5)	929 (12.5)	578 (9.7)	751 (19.5)	< 0.001
Hip fracture	817 (1.6)	442 (1.3)	156 (2.1)	105 (1.8)	114 (3.0)	< 0.001
Other fracture	2,174 (4.3)	1,259 (3.7)	377 (5.1)	300 (5.1)	238 (6.2)	< 0.001

Cognitive decline	765 (1.5)	258 (0.8)	142 (1.9)	128 (2.2)	237 (6.2)	< 0.001
Affective / emotional	3,343 (6.6)	1,770 (5.2)	613 (8.2)	471 (7.9)	489 (12.7)	< 0.001
Any arthritis	12,676 (24.9)	7,304 (21.6)	2,199 (29.6)	1,759 (29.7)	1,414 (36.7)	< 0.001
Drugs, n (%)						
Anti-hypertensives	22,998 (45.1)	14,110 (41.8)	3,572 (48.0)	3,040 (51.3)	2,276 (59.1)	< 0.001
Drugs for pain	13,056 (25.6)	7,421 (22.0)	2,350 (31.6)	1,649 (27.8)	1,636 (42.5)	< 0.001
Psychotropic drugs	6,353 (12.5)	3,415 (10.1)	1,193 (16.0)	862 (14.5)	883 (22.9)	< 0.001
Glasses, n (%)	43,251 (84.8)	29,594 (87.6)	5,333 (71.7)	5,405 (91.2)	2,919 (75.8)	< 0.001
Hearing aids, n (%)	3,162 (6.2)	1,690 (5.0)	339 (4.6)	738 (12.4)	395 (10.3)	< 0.001
Falls at baseline, n (%)	3,472 (6.8)	1,600 (4.7)	683 (9.2)	536 (9.0)	653 (16.9)	< 0.001

Abbreviations: n: number. P-values were computed by Pearson's chi-square for categorical variables and by ANOVA for the continuous variable age.

Table 3 Cross-sectional association between vision and hearing impairment and falls risk at baseline

	All (n = 50,986)			Men (n = 22,118)			Women (n = 28,868)		
	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value
Model 1									
Good vision and hearing	1,600	1 (ref)		449	1 (ref)		1,151	1 (ref)	
Impaired vision only	683	1.77 [1.61; 1.95]	< 0.001	154	1.81 [1.50; 2.19]	< 0.001	529	1.75 [1.57; 1.96]	< 0.001
Impaired hearing only	536	1.72 [1.55; 1.91]	< 0.001	227	2.00 [1.69; 2.36]	< 0.001	309	1.56 [1.36; 1.79]	< 0.001
Impaired vision and hearing	653	2.81 [2.53; 3.12]	< 0.001	176	2.88 [2.38; 3.48]	< 0.001	477	2.77 [2.45; 3.14]	< 0.001
Model 2									
Good vision and hearing	1,600	1 (ref)		449	1 (ref)		1,151	1 (ref)	
Impaired vision only	683	1.34 [1.22; 1.49]	< 0.001	154	1.32 [1.08; 1.61]	0.007	529	1.35 [1.20; 1.52]	< 0.001
Impaired hearing only	536	1.34 [1.20; 1.50]	< 0.001	227	1.57 [1.32; 1.86]	< 0.001	309	1.21 [1.05; 1.39]	0.010
Impaired vision and hearing	653	1.67 [1.50; 1.87]	< 0.001	176	1.66 [1.35; 2.04]	< 0.001	477	1.68 [1.47; 1.93]	< 0.001

Odds ratios and 95% confidence intervals are calculated by binary logistic regression. Model 1: adjusted for age and sex. Model 2: adjusted for age, sex, self-rated health, heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder, any arthritis, anti-hypertensives, drugs for pain, psychotropic drugs, use of glasses, use of hearing aids. Number of participants reporting falls at baseline: all participants: 3,472; men: 1,006; women: 2,466. Abbreviations: n: number; OR: odds ratios; CI: confidence intervals; ref: reference.

Table 4 Longitudinal association between visual and hearing impairment and falls risk at follow-up

	All (n = 50,986)			Men (n = 22,118)			Women (n = 28,868)		
	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value
Model 1									
Good vision and hearing	2,094	1 (ref)		663	1 (ref)		1,431	1 (ref)	
Impaired vision only	798	1.58 [1.45; 1.73]	< 0.001	212	1.66 [1.41; 1.95]	< 0.001	586	1.56 [1.40; 1.73]	< 0.001
Impaired hearing only	597	1.39 [1.26; 1.54]	< 0.001	248	1.37 [1.17; 1.59]	< 0.001	349	1.42 [1.25; 1.61]	< 0.001
Impaired vision and hearing	725	2.30 [2.08; 2.53]	< 0.001	228	2.31 [1.95; 2.73]	< 0.001	497	2.30 [2.04; 2.59]	< 0.001
Model 2									
Good vision and hearing	2,094	1 (ref)		663	1 (ref)		1,431	1 (ref)	
Impaired vision only	798	1.23 [1.12; 1.35]	< 0.001	212	1.24 [1.04; 1.47]	0.015	586	1.22 [1.10; 1.36]	< 0.001
Impaired hearing only	597	1.14 [1.03; 1.26]	0.011	248	1.12 [0.96; 1.32]	0.157	349	1.15 [1.01; 1.31]	0.040
Impaired vision and hearing	725	1.45 [1.30; 1.61]	< 0.001	228	1.40 [1.17; 1.68]	< 0.001	497	1.47 [1.29; 1.67]	< 0.001

Model 3									
Good vision and hearing	2,094	1 (ref)		663	1 (ref)		1,431	1 (ref)	
Impaired vision only	798	1.19 [1.08; 1.31]	< 0.001	212	1.22 [1.02; 1.45]	0.028	586	1.18 [1.05; 1.32]	0.004
Impaired hearing only	597	1.10 [0.99; 1.22]	0.065	248	1.07 [0.91; 1.25]	0.436	349	1.12 [0.98; 1.29]	0.089
Impaired vision and hearing	725	1.33 [1.20; 1.49]	< 0.001	228	1.33 [1.10; 1.60]	0.003	497	1.34 [1.17; 1.53]	< 0.001

Odds ratios and 95% confidence intervals are calculated by binary logistic regression. Model 1: adjusted for age and sex. Model 2: adjusted for age, sex, self-rated health, heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder, any arthritis, anti-hypertensives, drugs for pain, psychotropic drugs, use of glasses, use of hearing aids. Model 3: adjusted for all co-variates of Model 2 and falls at baseline. Number of participants reporting falls at follow-up: all participants: 4,214; men: 1,351; women: 2,863. Abbreviations: n: number; OR: odds ratios; CI: confidence intervals; ref: reference. At 2-year follow-up (Wave 7), participants were asked whether they had had any fall(s) in the six months prior to interview.

Supplementary Table 1 Characteristics at baseline (Wave 6) of participants who were included in the final sample and those who were excluded between Wave 6 and 7

	Final sample (n = 50,986)	Excluded at follow-up (n = 15,094)	P value
Age (years), mean (SD)	67.1 (9.5)	68.1 (11.1)	< 0.001
Women, n (%)	28,868 (56.6)	8,059 (53.4)	< 0.001
Vision and hearing categories, n (%):			
Good vision and hearing	33,767 (66.2)	9,380 (62.1)	< 0.001
Impaired vision only	7,437 (14.6)	2,515 (16.7)	
Impaired hearing only	5,929 (11.6)	1,616 (10.7)	
Impaired vision and hearing	3,853 (7.6)	1,583 (10.5)	
Self-rated health, n (%):			
Good	31,492 (61.8)	8,384 (55.5)	< 0.001
Poor	19,494 (38.2)	6,710 (44.5)	
Co-morbidities, n (%):			
Heart attack	5,679 (11.1)	1,953 (12.9)	< 0.001
Hypertension	21,357 (41.9)	6,128 (40.6)	0.005
High cholesterol	12,710 (24.9)	3,634 (24.1)	0.033
Stroke	1,718 (3.4)	718 (4.8)	< 0.001
Diabetes	6,877 (13.5)	2,238 (14.8)	< 0.001
Chronic lung disease	3,092 (6.1)	1,071 (7.1)	< 0.001
Cancer	2,157 (4.2)	877 (5.8)	< 0.001
Parkinson's disease	387 (0.8)	193 (1.3)	< 0.001
Cataracts	4,107 (8.1)	1,308 (8.7)	0.016
Hip fracture	817 (1.6)	356 (2.4)	< 0.001
Other fracture	2,174 (4.3)	678 (4.5)	0.226
Cognitive decline	765 (1.5)	601 (4.0)	< 0.001
Affective / emotional	3,343 (6.6)	1,116 (7.4)	< 0.001
Any arthritis	12,676 (24.9)	3,529 (23.4)	< 0.001
Drugs, n (%)			
Anti-hypertensives	22,998 (45.1)	6,643 (44.0)	0.017
Drugs for pain	13,056 (25.6)	4,394 (29.1)	< 0.001

Psychotropic drugs	6,353 (12.5)	2,178 (14.4)	< 0.001
Glasses, n (%)	43,251 (84.8)	12,225 (81.0)	< 0.001
Hearing aids, n (%)	3,162 (6.2)	990 (6.6)	0.112
Falls at baseline, n (%)	3,472 (6.8)	1,399 (9.3)	< 0.001

Abbreviation: n: number. P-values were computed by Pearson's chi-square for categorical variables and by t-test for the continuous variable age.

Supplementary Table 2 Characteristics of participants aged 80 years and older at baseline and stratified by sex

	All (n = 5,902)	Men (n = 2,422)	Women (n = 3,480)	P value
Age (years), mean (SD)	83.9 (3.5)	83.7 (3.3)	84.1 (3.6)	< 0.001
Vision and hearing categories, n (%):				
Good vision and hearing	2,570 (43.5)	1,110 (45.8)	1,460 (42.0)	<
Impaired vision only	980 (16.6)	319 (13.2)	661 (19.0)	0.001
Impaired hearing only	1,116 (18.9)	526 (21.7)	590 (17.0)	
Impaired vision and hearing	1,236 (20.9)	467 (19.3)	769 (22.1)	
Self-rated health, n (%):				
Good	2,422 (41.0)	1,167 (48.2)	1,255 (36.1)	<
Poor	3,480 (59.0)	1,255 (51.8)	2,225 (63.9)	0.001
Co-morbidities, n (%):				
Heart attack	1,327 (22.5)	595 (24.6)	732 (21.0)	0.001
Hypertension	3,185 (54.0)	1,198 (49.5)	1,987 (57.1)	< 0.001
High cholesterol	1,638 (27.8)	576 (23.8)	1,062 (30.5)	< 0.001
Stroke	381 (6.5)	170 (7.0)	211 (6.1)	0.142
Diabetes	1,043 (17.7)	427 (17.6)	616 (17.7)	0.944
Chronic lung disease	450 (7.6)	219 (9.0)	231 (6.6)	0.001
Cancer	294 (5.0)	156 (6.4)	138 (4.0)	< 0.001
Parkinson’s disease	110 (1.9)	51 (2.1)	59 (1.7)	0.252
Cataracts	1,180 (20.0)	425 (17.5)	755 (21.7)	< 0.001
Hip fracture	252 (4.3)	68 (2.8)	184 (5.3)	< 0.001
Other fracture	338 (5.7)	84 (3.5)	254 (7.3)	< 0.001

Cognitive decline	363 (6.2)	125 (5.2)	238 (6.8)	0.008
Affective / emotional	425 (7.2)	103 (4.3)	322 (9.3)	< 0.001
Any arthritis	2,110 (35.8)	576 (23.8)	1,534 (44.1)	< 0.001
Drugs, n (%)				
Anti-hypertensives	3,657 (62.0)	1,418 (58.5)	2,239 (64.3)	< 0.001
Drugs for pain	2,148 (36.4)	637 (26.3)	1,511 (43.4)	< 0.001
Psychotropic drugs	1,143 (19.4)	294 (12.1)	849 (24.4)	< 0.001
Glasses, n (%)	4,875 (82.6)	1,969 (81.3)	2,906 (83.5)	0.028
Hearing aids, n (%)	1,055 (17.9)	510 (21.1)	545 (15.7)	< 0.001
Falls at baseline, n (%)	932 (15.8)	237 (9.8)	695 (20.0)	< 0.001

Abbreviation: n: number. P-values were computed by Pearson's chi-square for categorical variables and by t-test for the continuous variable age.

Supplementary Table 3 Characteristics of men at baseline by visual and hearing impairment

	All (n = 22,118)	Good vision and hearing (n = 14,557)	Impaired vision only (n = 2,670)	Impaired hearing only (n = 3,260)	Impaired vision and hearing (n = 1,631)	P value
Age (years), mean (SD)	67.2 (9.1)	66.0 (8.6)	67.2 (9.5)	69.9 (9.1)	72.4 (10.1)	< 0.001
Self-rated health, n (%):						
Good	14,213 (64.3)	10,605 (72.9)	1,364 (51.1)	1,755 (53.8)	489 (30.0)	< 0.001
Poor	7,905 (35.7)	3,952 (27.1)	1,306 (48.9)	1,505 (46.2)	1,142 (70.0)	
Co-morbidities, n (%):						
Heart attack	3,010 (13.6)	1,664 (11.4)	417 (15.6)	555 (17.0)	374 (22.9)	< 0.001
Hypertension	9,194 (41.6)	5,774 (39.7)	1,105 (41.4)	1,539 (47.2)	776 (47.6)	< 0.001
High cholesterol	5,225 (23.6)	3,314 (22.8)	633 (23.7)	854 (26.2)	424 (26.0)	< 0.001
Stroke	921 (4.2)	483 (3.3)	155 (5.8)	149 (4.6)	134 (8.2)	< 0.001
Diabetes	3,302 (14.9)	2,003 (13.8)	444 (16.6)	525 (16.1)	330 (20.2)	< 0.001
Chronic lung disease	1,447 (6.5)	765 (5.3)	195 (7.3)	280 (8.6)	207 (12.7)	< 0.001
Cancer	951 (4.3)	550 (3.8)	120 (4.5)	188 (5.8)	93 (5.7)	< 0.001
Parkinson’s disease	197 (0.9)	84 (0.6)	38 (1.4)	33 (1.0)	42 (2.6)	< 0.001
Cataracts	1,493 (6.8)	696 (4.8)	290 (10.9)	254 (7.8)	253 (15.5)	< 0.001
Hip fracture	300 (1.4)	172 (1.2)	52 (1.9)	49 (1.5)	27 (1.7)	0.008
Other fracture	856 (3.9)	522 (3.6)	120 (4.5)	134 (4.1)	80 (4.9)	0.011
Cognitive decline	306 (1.4)	94 (0.6)	57 (2.1)	64 (2.0)	91 (5.6)	< 0.001

Affective / emotional	935 (4.2)	466 (3.2)	139 (5.2)	187 (5.7)	143 (8.8)	< 0.001
Any arthritis	3,794 (17.2)	2,163 (14.9)	515 (19.3)	713 (21.9)	403 (24.7)	< 0.001
Drugs, n (%)						
Anti-hypertensives	10,025 (45.3)	6,295 (43.2)	1,221 (45.7)	1,645 (50.5)	864 (53.0)	< 0.001
Drugs for pain	4,187 (18.9)	2,364 (16.2)	607 (22.7)	697 (21.4)	519 (31.8)	< 0.001
Psychotropic drugs	1,744 (7.9)	916 (6.3)	267 (10.0)	306 (9.4)	255 (15.6)	< 0.001
Glasses, n (%)	18,334 (82.9)	12,489 (85.8)	1,742 (65.2)	2,937 (90.1)	1,166 (71.5)	< 0.001
Hearing aids, n (%)	1,694 (7.7)	942 (6.5)	148 (5.5)	415 (12.7)	189 (11.6)	< 0.001
Falls at baseline, n (%)	1,006 (4.5)	449 (3.1)	154 (5.8)	227 (7.0)	176 (10.8)	< 0.001

Abbreviations: n: number. P-values were computed by Pearson's chi-square for categorical variables and by ANOVA for the continuous variable age.

Supplementary Table 4 Characteristics of women at baseline by categories of visual and hearing impairment

	All (n = 28,868)	Good vision and hearing (n = 19,210)	Impaired vision only (n = 4,767)	Impaired hearing only (n = 2,669)	Impaired vision and hearing (n = 2,222)	P value
Age (years), mean (SD)	67.0 (9.7)	65.4 (9.0)	67.6 (9.9)	70.8 (9.8)	74.4 (10.2)	< 0.001
Self-rated health, n (%):						
Good	17,279 (59.9)	13,383 (69.7)	2,240 (47.0)	1,213 (45.4)	443 (19.9)	< 0.001
Poor	11,589 (40.1)	5,827 (30.3)	2,527 (53.0)	1,456 (54.6)	1,779 (80.1)	
Co-morbidities, n (%):						
Heart attack	2,669 (9.2)	1,317 (6.9)	537 (11.3)	380 (14.2)	435 (19.6)	< 0.001
Hypertension	12,163 (42.1)	7,339 (38.2)	2,183 (45.8)	1,299 (48.7)	1,342 (60.4)	< 0.001
High cholesterol	7,485 (25.9)	4,504 (23.4)	1,339 (28.1)	830 (31.1)	812 (36.5)	< 0.001
Stroke	797 (2.8)	392 (2.0)	158 (3.3)	97 (3.6)	150 (6.8)	< 0.001
Diabetes	3,575 (12.4)	1,936 (10.1)	718 (15.1)	420 (15.7)	501 (22.5)	< 0.001
Chronic lung disease	1,645 (5.7)	905 (4.7)	337 (7.1)	198 (7.4)	205 (9.2)	< 0.001
Cancer	1,206 (4.2)	711 (3.7)	231 (4.8)	142 (5.3)	122 (5.5)	< 0.001
Parkinson’s disease	190 (0.7)	87 (0.5)	34 (0.7)	27 (1.0)	42 (1.9)	< 0.001
Cataracts	2,614 (9.1)	1,153 (6.0)	639 (13.4)	324 (12.1)	498 (22.4)	< 0.001
Hip fracture	517 (1.8)	270 (1.4)	104 (2.2)	56 (2.1)	87 (3.9)	< 0.001
Other fracture	1,318 (4.6)	737 (3.8)	257 (5.4)	166 (6.2)	158 (7.1)	< 0.001
Cognitive decline	459 (1.6)	164 (0.9)	85 (1.8)	64 (2.4)	146 (6.6)	< 0.001

Affective / emotional	2,408 (8.3)	1,304 (6.8)	474 (9.9)	284 (10.6)	346 (15.6)	< 0.001
Any arthritis	8,882 (30.8)	5,141 (26.8)	1,684 (35.3)	1,046 (39.2)	1,011 (45.5)	< 0.001
Drugs, n (%)						
Anti-hypertensives	12,973 (44.9)	7,815 (40.7)	2,351 (49.3)	1,395 (52.3)	1,412 (63.5)	< 0.001
Drugs for pain	8,869 (30.7)	5,057 (26.3)	1,743 (36.6)	952 (35.7)	1,117 (50.3)	< 0.001
Psychotropic drugs	4,609 (16.0)	2,499 (13.0)	926 (19.4)	556 (20.8)	628 (28.3)	< 0.001
Glasses, n (%)	24,917 (86.3)	17,105 (89.0)	3,591 (75.3)	2,468 (92.5)	1,753 (78.9)	< 0.001
Hearing aids, n (%)	1,468 (5.1)	748 (3.9)	191 (4.0)	323 (12.1)	206 (9.3)	< 0.001
Falls at baseline, n (%)	2,466 (8.5)	1,151 (6.0)	529 (11.1)	309 (11.6)	477 (21.5)	< 0.001

Abbreviations: n: number. P-values were computed by Pearson's chi-square for categorical variables and by ANOVA for the continuous variable age.

Supplementary Table 5 Cross-sectional association between categories of visual and hearing impairment and falls risk, among participants aged 80 years and older

	Participants aged ≥ 80 years (n = 5,902)			Men aged ≥ 80 years (n = 2,422)			Women ≥ 80 years (n = 3,480)		
	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value
Model 1									
Good vision and hearing	303	1 (ref)		86	1 (ref)		217	1 (ref)	
Impaired vision only	173	1.48 [1.20; 1.81]	< 0.001	29	1.14 [0.73; 1.78]	0.560	144	1.59 [1.26; 2.01]	< 0.001
Impaired hearing only	164	1.32 [1.07; 1.62]	0.009	55	1.35 [0.95; 1.93]	0.097	109	1.29 [1.00; 1.66]	0.050
Impaired vision and hearing	292	2.17 [1.81; 2.60]	< 0.001	67	1.88 [1.34; 2.65]	< 0.001	225	2.31 [1.86; 2.86]	< 0.001
Model 2									
Good vision and hearing	303	1 (ref)		86	1 (ref)		217	1 (ref)	
Impaired vision only	173	1.13 [0.91; 1.41]	0.259	29	0.75 [0.46; 1.20]	0.226	144	1.27 [0.99; 1.62]	0.062
Impaired hearing only	164	1.09 [0.88; 1.35]	0.431	55	1.08 [0.74; 1.57]	0.702	109	1.09 [0.83; 1.42]	0.532
Impaired vision and hearing	292	1.40 [1.15; 1.71]	0.001	67	1.08 [0.73; 1.59]	0.701	225	1.56 [1.23; 1.97]	< 0.001

Odds ratios and 95% confidence intervals are calculated by binary logistic regression. Model 1: adjusted for age and sex. Model 2: adjusted for age, sex, self-rated health, heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder, any arthritis, anti-hypertensives, drugs for pain, psychotropic drugs,

use of glasses, use of hearing aids. Number of participants aged 80 years and older reporting falls at baseline: all participants: 932; men: 237; women: 695. Abbreviations: n: number; OR: odds ratios; CI: confidence intervals; ref: reference.

Supplementary Table 6 Longitudinal association between covariates and falls risk at follow-up for the total cohort and stratified by sex (fully adjusted)

	All (n = 50,986)		Men (n = 22,118)		Women (n = 28,868)	
	OR [95% CI]	**P value**	**OR [95% CI]**	**P value**	**OR [95% CI]**	**P value**
Age (years)	1.04 [1.04; 1.05]	< 0.001	1.05 [1.04; 1.06]	< 0.001	1.04 [1.03; 1.04]	< 0.001
Sex (women versus men)	1.39 [1.29; 1.49]	< 0.001	na		na	
Self-rated health (poor versus good)	1.58 [1.46; 1.71]	< 0.001	1.66 [1.45; 1.90]	< 0.001	1.54 [1.39; 1.69]	< 0.001
Co-morbidities (yes versus no)						
Heart attack	1.11 [1.02; 1.22]	0.023	1.06 [0.92; 1.23]	0.417	1.15 [1.02; 1.30]	0.021
Hypertension	0.99 [0.88; 1.11]	0.848	1.20 [0.99; 1.45]	0.065	0.89 [0.77; 1.03]	0.124
High cholesterol	0.95 [0.88; 1.03]	0.189	0.92 [0.80; 1.06]	0.241	0.97 [0.88; 1.06]	0.480
Stroke	1.48 [1.29; 1.70]	< 0.001	1.67 [1.36; 2.05]	< 0.001	1.32 [1.09; 1.60]	0.004
Diabetes	1.25 [1.14; 1.37]	< 0.001	1.15 [1.00; 1.34]	0.059	1.32 [1.18; 1.47]	< 0.001
Chronic lung disease	1.21 [1.08; 1.36]	0.001	1.25 [1.03; 1.50]	0.022	1.17 [1.01; 1.36]	0.041
Cancer	0.94 [0.81; 1.10]	0.439	0.98 [0.76; 1.25]	0.837	0.91 [0.75; 1.10]	0.319
Parkinson’s disease	2.35 [1.85; 3.00]	< 0.001	2.89 [2.05; 4.09]	< 0.001	1.89 [1.35; 2.65]	< 0.001
Cataracts	1.05 [0.95; 1.16]	0.354	1.15 [0.96; 1.38]	0.135	1.02 [0.90; 1.16]	0.740
Hip fracture	1.36 [1.12; 1.65]	0.002	1.53 [1.08; 2.17]	0.017	1.33 [1.06; 1.67]	0.014
Other fracture	1.19 [1.04; 1.37]	0.011	1.15 [0.89; 1.49]	0.282	1.23 [1.05; 1.44]	0.012
Cognitive decline	1.21 [1.00; 1.46]	0.051	1.37 [1.00; 1.87]	0.050	1.12 [0.88; 1.41]	0.361

Affective / emotional	1.18 [1.05; 1.32]	0.007	0.95 [0.75; 1.21]	0.672	1.27 [1.11; 1.45]	0.001
Any arthritis	1.17 [1.08; 1.26]	< 0.001	1.28 [1.11; 1.47]	0.001	1.15 [1.05; 1.25]	0.004
Drugs (use versus no use)						
Anti-hypertensives	1.01 [0.90; 1.13]	0.903	0.92 [0.76; 1.11]	0.389	1.07 [0.92; 1.23]	0.402
Drugs for pain	1.40 [1.30; 1.52]	< 0.001	1.48 [1.29; 1.70]	< 0.001	1.37 [1.25; 1.51]	< 0.001
Psychotropic drugs	1.51 [1.38; 1.65]	< 0.001	1.76 [1.49; 2.10]	< 0.001	1.43 [1.29; 1.59]	< 0.001
Falls at baseline (yes versus no)	3.52 [3.22; 3.84]	< 0.001	3.60 [3.05; 4.26]	< 0.001	3.50 [3.15; 3.88]	< 0.001
Glasses (use versus no use)	1.11 [1.01; 1.22]	0.039	1.09 [0.94; 1.28]	0.262	1.12 [0.99; 1.26]	0.066
Hearing aids (use versus no use)	0.92 [0.82; 1.04]	0.179	0.91 [0.76; 1.10]	0.332	0.95 [0.81; 1.12]	0.527

Odds ratios and 95% confidence intervals are calculated by binary logistic regression, using age (years) as a continuous variable and all other variables as categorical variables. For categorical variables, the reference categories are: men, for sex; good, for self-rated health; absence of the disease, for each co-morbidity; not reporting falls, for falls at baseline; not taking the medication, for each drug; not using glasses, for glasses; not using hearing aids, for hearing aids. All analyses were adjusted for: age, sex, self-rated health, heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder, any arthritis, anti-hypertensives, drugs for pain, psychotropic drugs, use of glasses, use of hearing aids and falls at baseline (Model 3). Number of participants reporting falls at follow-up in each category: all participants: 4,214; men: 1,351; women: 2,863. Abbreviations: n: number; OR: odds ratios; CI: confidence intervals; ref: reference; na: not applicable. At 2-year follow-up (Wave 7), participants were asked whether they had had any fall(s) in the six months prior to interview.

Supplementary Table 7 Longitudinal association between categories of visual and hearing impairment and falls risk at follow-up, for the total cohort and stratified by sex, after excluding participants who reported previous falls at baseline

	All (n = 47,514)			Men (n = 21,112)			Women (n = 26,402)		
	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value
Model 1									
Good vision and hearing	1,630	1 (ref)		551	1 (ref)		1,079	1 (ref)	
Impaired vision only	564	1.51 [1.36; 1.67]	< 0.001	162	1.54 [1.29; 1.85]	< 0.001	402	1.49 [1.32; 1.68]	< 0.001
Impaired hearing only	429	1.33 [1.18; 1.49]	< 0.001	191	1.31 [1.10; 1.55]	0.003	238	1.35 [1.16; 1.57]	< 0.001
Impaired vision and hearing	472	2.17 [1.93; 2.43]	< 0.001	173	2.23 [1.85; 2.69]	< 0.001	299	2.14 [1.85; 2.48]	< 0.001
Model 2									
Good vision and hearing	1,630	1 (ref)		551	1 (ref)		1,079	1 (ref)	
Impaired vision only	564	1.21 [1.09; 1.34]	< 0.001	162	1.19 [0.98; 1.44]	0.084	402	1.21 [1.07; 1.38]	0.003
Impaired hearing only	429	1.13 [1.01; 1.27]	0.040	191	1.12 [0.94; 1.34]	0.206	238	1.13 [0.97; 1.32]	0.113

Impaired vision and hearing	472	1.48 [1.31; 1.67]	< 0.001	173	1.46 [1.20; 1.79]	< 0.001	299	1.49 [1.27; 1.73]	< 0.001

Odds ratios and 95% confidence intervals are calculated by binary logistic regression. Model 1: adjusted for age and sex. Model 2: adjusted for age, sex, self-rated health, heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder, any arthritis, anti-hypertensives, drugs for pain, psychotropic drugs, use of glasses, use of hearing aids. Number of participants reporting falls at follow-up: all participants: 3,095; men: 1,077; women: 2,018. Abbreviations: n: number; OR: odds ratios; CI: confidence intervals; ref: reference. At 2-year follow-up (Wave 7), participants were asked whether they had had any fall(s) in the six months prior to interview.

Supplementary Table 8 Age-stratified longitudinal association between categories of visual and hearing impairment and falls risk at follow-up (fully adjusted)

	All (n = 50,986)			**Men (n = 22,118)**			**Women (n = 28,868)**		
	n of falls	**OR [95% CI]**	**P value**	**n of falls**	**OR [95% CI]**	**P value**	**n of falls**	**OR [95% CI]**	**P value**
Aged 50 to 64 years		n = 21,986			n = 9,252			n = 12,734	
Good vision and hearing	602	1 (ref)		165	1 (ref)		437	1 (ref)	
Impaired vision only	204	1.28 [1.07; 1.53]	0.007	49	1.16 [0.82; 1.66]	0.403	155	1.33 [1.08; 1.63]	0.007
Impaired hearing only	114	1.36 [1.09; 1.69]	0.007	44	1.25 [0.87; 1.80]	0.230	70	1.42 [1.07; 1.88]	0.015
Impaired vision and hearing	92	1.64 [1.26; 2.12]	< 0.001	39	1.95 [1.29; 2.94]	0.002	53	1.42 [1.01; 1.99]	0.043
Aged ≥ 65 years		n = 29,000			n = 12,866			n = 16,134	
Good vision and hearing	1,492	1 (ref)		498	1 (ref)		994	1 (ref)	

Impaired vision only	594	1.15 [1.03; 1.28]	0.016	163	1.21 [0.99; 1.48]	0.063	431	1.12 [0.98; 1.27]	0.103
Impaired hearing only	483	1.03 [0.92; 1.16]	0.642	204	1.01 [0.84; 1.21]	0.910	279	1.04 [0.89; 1.21]	0.630
Impaired vision and hearing	633	1.27 [1.12; 1.43]	< 0.001	189	1.20 [0.98; 1.48]	0.080	444	1.30 [1.12; 1.50]	< 0.001

Odds ratios and 95% confidence intervals are calculated by binary logistic regression. All analyses were adjusted for age, sex, self-rated health, heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder; any arthritis, anti-hypertensives, drugs for pain, psychotropic drugs, use of glasses, use of hearing aids and falls at baseline (Model 3). Number of participants reporting falls at follow-up in each category: among those aged 50 to 64 years: all participants: 1,012; men: 297; women: 715; among those aged ≥ 65 years: all participants: 3,202; men: 1,054; women: 2,148. Abbreviations: n: number; OR: odds ratios; CI: confidence intervals; ref: reference. At 2-year follow-up (Wave 7), participants were asked whether they had had any fall(s) in the six months prior to interview.

Supplementary Table 9 Longitudinal association between categories of visual and hearing impairment and falls risk at follow-up, among participants aged 80 years and older

	Participants aged ≥ 80 years (n = 5,902)			Men aged ≥ 80 years (n = 2,422)			Women ≥ 80 years (n = 3,480)		
	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value	n of falls	OR [95% CI]	P value
Model 1									
Good vision and hearing	409	1 (ref)		142	1 (ref)		267	1 (ref)	
Impaired vision only	208	1.33 [1.11; 1.61]	0.003	49	1.18 [0.83; 1.69]	0.351	159	1.39 [1.11; 1.74]	0.004
Impaired hearing only	188	1.06 [0.88; 1.29]	0.533	69	1.00 [0.73; 1.36]	0.991	119	1.10 [0.87; 1.41]	0.425
Impaired vision and hearing	331	1.77 [1.49; 2.09]	< 0.001	105	1.87 [1.41; 2.47]	< 0.001	226	1.73 [1.40; 2.12]	< 0.001
Model 2									
Good vision and hearing	409	1 (ref)		142	1 (ref)		267	1 (ref)	
Impaired vision only	208	1.09 [0.90; 1.33]	0.379	49	0.85 [0.58; 1.24]	0.405	159	1.18 [0.94; 1.49]	0.157
Impaired hearing only	188	0.93 [0.76; 1.13]	0.468	69	0.83 [0.60; 1.15]	0.260	119	0.99 [0.78; 1.28]	0.965
Impaired vision and hearing	331	1.25 [1.05; 1.50]	0.015	105	1.20 [0.87; 1.65]	0.258	226	1.28 [1.02; 1.60]	0.031
Model 3									
Good vision and hearing	409	1 (ref)		142	1 (ref)		267	1 (ref)	
Impaired vision only	208	1.08 [0.88; 1.31]	0.468	49	0.88 [0.60; 1.28]	0.499	159	1.14 [0.90; 1.45]	0.272

Impaired hearing only	188	0.92 [0.75; 1.12]	0.397	69	0.82 [0.59; 1.13]	0.229	119	0.99 [0.77; 1.27]	0.911
Impaired vision and hearing	331	1.19 [0.99; 1.44]	0.060	105	1.20 [0.87; 1.65]	0.272	226	1.19 [0.94; 1.49]	0.146

Odds ratios and 95% confidence intervals are calculated by binary logistic regression. Model 1: adjusted for age and sex. Model 2: adjusted for age, sex, self-rated health, heart attack, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, cancer, Parkinson's, cataracts, hip fracture, other fractures, cognitive impairment, affective / emotional disorder, any arthritis, falls at baseline, anti-hypertensives, drugs for pain, psychotropic drugs, use of glasses, use of hearing aids. Model 3: adjusted for all co-variates of Model 2 and falls at baseline. Number of participants aged 80 years and older reporting falls at follow-up: all participants: 1,136; men: 365; women: 771. Abbreviations: n: number; OR: odds ratios; CI: confidence intervals; ref: reference. At 2-year follow-up (Wave 7), participants were asked whether they had had any fall(s) in the six months prior to interview.