Hearing status gradients in the risk of hospitalization among Chinese middle-aged and older adults

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Research

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Abstract

Background: Hearing is one of the basic means of perception and communication, which is closely related with quality of life. However, hearing impairment is often unrecognized and undertreated, and impaired hearing may lead to greater burden of diseases as well as risk of hospitalization. To gain further insight into the association between hearing and hospitalization, we examined the shape and magnitude of hearing status gradients in the risk of hospitalization among Chinese middle-aged and older adults. Methods: We obtained data from a retrospective survey of the China Health and Retirement Longitudinal Study (CHARLS) conducted in 2011, 2013 and 2015, including 11,721 participants aged 45 years old and above with no hospitalization in 2011 baseline. Hospitalization variables included time to incident (first) hospitalization, annual number of hospitalizations and duration of last-time hospitalization. Cox proportional hazards models, negative binomial models and lognormal regression were fitted to examine the relationship between self-rated hearing status gradients and risk of hospitalization. Results: Of the total 11,721 participants, 54.46% reported having fair or poor hearing and 20.94% experienced at least one hospitalization during the study period. Older adults were exposed to higher risk of hospitalization than the middle-aged adults. For older adults, compared with excellent or very good hearing people, those with good, fair and poor hearing experienced a shorter time to incident (first) hospitalization, a greater annual number of hospitalizations and a longer last-time duration of hospitalization with the deterioration of hearing. However, there was no significant association for the middle-aged adults. Conclusions: We found a gradient decrease in time to first hospitalization, an increase in annual number of hospitalizations and duration of last-time hospitalization with the deterioration of hearing status in older adults. Actions should be taken to prevent and treat their hearing impairment, so as to decrease risk of hospitalization and improve their life quality.

Introduction

Hearing impairment is one of the most common sensory dysfunctions and has become a major public health concern worldwide [1]. In 2019, over 5% of the world population or approximately 466 million people had disabling hearing impairment [2]. The risk of hearing impairment increases rapidly with age. As reported in the United States in 2018, approximately one in three people in the United States between the ages of 65 and 74 had hearing loss, and nearly half of those aged 75 and above reported difficulty in hearing [3]. While in China, according to the Second China National Sample Survey on Disability revealed in 2006, the prevalence rate of hearing disability (moderate hearing impairment and above) among older adults over 60 years old in China was about 11% [4, 5], ranking first among the six categories of disability (hearing, visual, speech, physical, intellectual and mental disabilities) [6]. Hearing impairment impedes social communication and participation, lowers cognitive ability, and leads to negative emotions such as loneliness, sadness, despair and helplessness. Impaired hearing reduces life quality and aggravates psychological burden, thus affecting people's health extensively [7, 8].

Inpatient cost occupies a large and increasing portion of healthcare budget in China. According to a report of national health services survey in China in 2013, the hospitalization rate of Chinese middle-aged and

older adults increased with age. The hospitalization rate of those 55–64 years old was 12.4% and for the older adults aged 65 and above, it was up to 19.9% [9]. With the increase of medical expenses and utilization rate of inpatient services, it is necessary to cut down inpatient hospitalization expenses from the root of prevention. Prior studies have revealed that individual characteristics, including age, race, residency and health status, were associated with hospitalization. Being older, black, living in rural counties and having poor health were all risk factors of hospitalization [10–12]. Besides, hearing impairment, as one of the most serious chronic diseases, can also lead to a greater risk of hospitalization for older adults aged 70 and above in the U.S [13, 14]. However, the relationship of hearing and hospitalization for a larger age group has not been fully studied, especially in less developed countries.

Given the current situation of hearing and hospitalization in China's healthcare environment, this study was designed to further explore the relationship between hearing status and risk of hospitalization. We focused on the middle-aged and older adults aged 45 years old and above, whose hearing status were relatively worse and needed more attention. We aimed to contribute to the extant literature on hearing and hospitalization in developing countries.

Methods

Study Population

We obtained information from the China Health and Retirement Longitudinal Study (CHARLS) 2011, 2013 and 2015, eying on the community-dwelling Chinese adults whose age was 45 years old or above. CHARLS is a long-term tracking project, with its baseline survey conducted in 2011 and follow-up surveys in 2013 and 2015 respectively [15]. More detailed information can be seen from the website: http://charls.pku.edu.cn/index/zh-cn.html.

Of the total 17,708 participants in CHARLS 2011 baseline survey, we excluded participants who had not given information of hospitalization in 2011 (N = 198) and participants who had hospitalization in 2011 (N = 1,587). Then we excluded missing values of hospitalization in 2013 (N = 2,256) and in 2015 (N = 1,426). Of the remaining 12,241 participants who had no hospitalization in 2011, 10 participants were excluded for missing values in hearing status and 510 participants were excluded for missing values in covariates. The remaining 11,721 individuals constitute the analytical cohort. Figure 1 presented a flow chart of the study sample from the 2011 CHARLS through the follow-up surveys.

Hearing Status Variable

Individuals' hearing status was derived by asking "Is your hearing excellent, very good, good, fair, or poor (with a hearing aid if you normally use it and without if you normally do not)?" in CHARLS 2011. And individuals' hearing status was divided into 4 categories, 1= "excellent & very good", 2= "good", 3= "fair", and 4= "poor" according to individuals' subjective answers.

Hospitalization Variables

Hospitalization variables consist of three elements, “time to incident (first) hospitalization”, “annual number of hospitalizations” and “duration of last-time hospitalization”. In CHARLS 2011, 2013 and 2015, participants were asked to report any hospitalizations during the past 12 months and were asked some relevant questions to elicit such information. A hospitalization was defined as an illness episode resulting in overnight admission to an acute care hospital. Investigators adjudicated the details of each hospitalization using medical records and supporting documents. These data include primary and secondary admission diagnoses and dates of admission and discharge.

Time to incident (first) hospitalization was defined as the time from the date of study enrollment to the date of the first hospital admission. As CHARLS did not record the exact date of the first hospital admission, we defined the date as six months before the investigation date. Annual number of hospitalizations was defined as the number of hospitalizations per year. Duration of last-time hospitalization was defined as the date of last-time hospital admission to the date of discharge. Hospitalizations resulting in death and same-day hospitalizations were excluded from duration of hospitalization analyses.

Covariates

Covariates include participants’ age (continuous variable), gender (male/female), residency (rural/urban), marriage (married/alone), education (illiterate/elementary school/middle school/high school and above), occupation (agriculture/non-agriculture), chronic diseases including hypertension (yes/no), diabetes mellitus (yes/no), stroke (yes/no), cardiovascular disease (yes/no), smoke (current/ former/never). Besides, participants reported whether they had ever worn a hearing aid and hearing aid use (yes/no) were also included as a covariate.

Statistical Analyses

Given the age heterogeneity within the group [16–18], we explored the relationship between hearing and hospitalization stratified by two age groups: 45–59 years vs. 60 years and above. Characteristics of participants were examined by gradient self-rated hearing status using Pearson’s Chi-square test for categorical variables. Time to incident (first) hospitalization, annual number of hospitalizations and duration of last-time hospitalization by hearing status are tested by Kruskal-Wallis one-way analysis of variance and are corrected for multiple comparisons within groups using Scheffe correction.

Kaplan-Meier estimates and Cox proportional hazards regression models were applied to explore the relationship between self-rated hearing status gradients and risk of hospitalization, using time from enrollment to incident (first) hospital admission as the time scale [19]. Negative binomial models were applied to model the variation in annual number of hospitalizations with different hearing status gradients [20]. The association between hearing status and duration of last-time hospitalization was analyzed using lognormal regression [21]. The software Stata version 14.0 for Mac (Stata Corp, College Station, TX, USA) was utilized for statistical analyses. All hypothesis tests were two-sided, with a P-value less than 0.05 considered statistically significant.

Results

Participants’ Characteristics

Table 1 shows the baseline characteristics of 11,721 middle-aged and older adults without hospitalization in 2011. It was found that 1,786 (15.24%) participants had excellent or very good hearing, 3,552 (30.30%) had good hearing, 4,768 (40.68%) had fair hearing, and 1,615 (13.78%) had poor hearing. Compared to individuals with normal hearing, those with hearing impairment were more likely to be older, female, living in rural areas, less educated, having no spouse, engaged in agriculture work, with hypertension, stroke, cardiovascular disease, being a smoker, using a hearing aid and experiencing at least one hospitalization. But there were no significant differences in prevalence of diabetes mellitus according to their self-rated hearing status. More details of characteristics for participants without hospitalization in 2011 were shown in Table 1.

Table 1

Characteristics of participants with no hospitalization by hearing status in CHARLS 2011 (N = 11,721)

Characteristics	Total	Excellent & Very Good Hearing	Good Hearing	Fair Hearing	Poor Hearing	P-Value
Total, N(%)	11,722 (100.00)	1,786 (15.24)	3,552 (30.30)	4,768 (40.68)	1,615 (13.78)	—
Age, N(%)						
45–59	6,719 (57.32)	1,236 (10.55)	2,209 (18.85)	2,666 (22.75)	608 (5.19)	< 0.001
60+	5,002 (42.68)	550 (4.69)	1,343 (11.46)	2,102 (17.93)	1,007 (8.59)	
Gender, N(%)						
Male	5,633 (48.06)	930 (7.93)	1,736 (14.81)	2,201 (18.78)	766 (6.54)	< 0.001
Female	6,088 (51.94)	856 (7.30)	1,816 (15.49)	2,567 (21.90)	849 (7.24)	
Residency, N(%)						
Rural	9,558 (81.55)	1,383 (11.80)	2,829 (24.14)	3,950 (33.70)	1,396 (11.91)	< 0.001
Urban	2,163 (18.45)	403 (3.44)	723 (6.17)	818 (6.98)	219 (1.87)	
Education, N(%)						
Illiterate	3,257 (27.79)	387 (3.30)	910 (7.76)	1,308 (11.16)	652 (5.56)	< 0.001
Primary school	4,709 (40.18)	670 (5.72)	1,346 (11.48)	2,028 (17.30)	665 (5.67)	
Middle school	2,449 (20.89)	449 (3.83)	808 (6.89)	991 (8.45)	201 (1.71)	
High school and above	1,306 (11.14)	280 (2.39)	488 (4.16)	441 (3.76)	97 (0.83)	
Marriage, N(%)						
Having spouse	10,376 (88.52)	1,614 (13.77)	3,213 (27.41)	4,242 (36.19)	1,307 (11.15)	< 0.001
No spouse	1,345 (11.48)	172 (1.47)	339 (2.89)	526 (4.49)	308 (2.63)	
Occupation, N(%)						

*P < 0.05,**P < 0.01,***P < 0.001

Characteristics	Total	Excellent & Very Good Hearing	Good Hearing	Fair Hearing	Poor Hearing	P-Value
Agriculture	6,982 (59.57)	1,022 (8.72)	2,042 (17.42)	2,991 (25.52)	928 (7.91)	< 0.001
Non-agriculture	4,739 (40.43)	764 (6.52)	1,510 (12.88)	1,777 (15.16)	688 (5.87)	
Chronic diseases, N(%)						
Hypertension	2,679 (22.86)	349 (2.98)	733 (6.25)	1,165 (9.94)	432 (3.69)	< 0.001
Diabetes mellitus	586 (5.00)	88 (0.75)	157 (1.34)	247 (2.11)	94 (0.80)	0.162
Stroke	201 (1.71)	20 (0.17)	45 (0.38)	83 (0.71)	53 (0.45)	< 0.001
Cardiovascular disease	1,241 (10.59)	107 (0.91)	311 (2.65)	568 (4.85)	255 (2.18)	< 0.001
Smoking history, N(%)						
Current	3,799 (32.41)	637 (5.43)	1,157 (9.87)	1,501 (12.81)	504 (4.30)	< 0.001
Former	900 (7.68)	118 (1.01)	247 (2.11)	371 (3.17)	164 (1.40)	
Never	7,022 (59.91)	1,031 (8.80)	2,148 (18.33)	2,896 (24.71)	947 (8.08)	
Hearing aid use, N(%)	60 (0.51)	7 (0.06)	10 (0.09)	14 (0.12)	29 (0.25)	< 0.001
≥ 1 hospitalizations, N(%)	2,454 (20.94)	291 (2.48)	689 (5.88)	1,051 (8.97)	423 (3.61)	< 0.001
*P < 0.05,**P < 0.01,***P < 0.001						

Table 2 presents more details about the risk of hospitalization among adults by age groups and self-rated hearing status gradients. We can see that for those with hearing impairment and aged over 60 years old, they experienced larger risk of hospitalization, manifested by shorter time to incident (first) hospitalization ($p < 0.001$), greater annual number of hospitalizations ($p < 0.001$) and longer duration of last-time hospitalization ($p < 0.001$). While for those aged below 60 years old, there was no significant differences between hearing status and time to incident hospitalization ($p = 0.267$), annual number of hospitalizations ($p = 0.263$) and duration of last-time hospitalization ($p = 0.439$). Scheffe correction was used for multiple comparisons within different groups of hearing status [see Additional file 1].

Table 2
Risk of Hospitalization among Chinese middle-aged and older adults by hearing status and age groups, 2011–2015 (N = 11,721)

Incidence	Total	Excellent & Very Good Hearing	Good Hearing	Fair Hearing	Poor Hearing	P-Value
45–59 years old						
Time to first hospitalization (months)	44.64	45.11	44.75	44.52	43.79	0.267
Annual number of hospitalizations per capital	0.14	0.13	0.14	0.15	0.18	0.263
Duration of last-time hospitalization (days)	6.43	5.97	7.19	5.96	6.73	0.439
60 years old and above						
Time to first hospitalization (months)	43.28	44.69	43.79	42.97	42.45	< 0.001
Annual number of hospitalizations per capital	0.22	0.14	0.20	0.24	0.26	< 0.001
Duration of last-time hospitalization (days)	6.72	6.77	7.02	6.59	6.62	< 0.001

Figure 2 shows results of the Kaplan-Meier estimates. After conducting log-rank test, it is confirmed that the proportion never hospitalized was related with different hearing status. For those aged 45–59 years old, better hearing status was associated with larger gradient proportion never hospitalized ($p = 0.035$). And for those aged 60 years old and above, the effects were more significant ($p < 0.001$).

Time to First Hospitalization

The association between self-rated hearing status gradients (excellent & very good, good, fair, poor) and time to incident (first) hospitalization was examined using Cox proportional hazards models adjusted for demographic characteristics, e.g. age, gender, residency, education, marriage, occupation, chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular diseases), smoking history and hearing aid use (Table 3).

Table 3

Time to first hospitalization, annual number of hospitalizations and mean last-time duration of hospitalization, in Chinese middle-aged and older adults, by elevational hearing status gradients and age group (N = 11,721)

Hearing Status	Time to First Hospitalization [a]		Annual number of hospitalizations [b]		Mean Duration of Last-time Hospitalization [c]	
	Hazard Ratio (95% CI)	P-Value	Incidence Rate Ratio (95% CI)	P-Value	Factor Change (95% CI)	P-Value
45–59 years old						
Excellent & Very good Hearing (reference group)						
Good hearing	1.02 (0.86–1.21)	0.813	1.05 (0.85–1.30)	0.645	0.03 (-0.02-0.08)	0.188
Fair hearing	1.08 (0.91–127)	0.368	1.10 (0.90–1.35)	0.341	0.02 (-0.03-0.07)	0.362
Poor hearing	1.16 (0.93–1.45)	0.198	1.21 (0.90–1.62)	0.214	0.06 (-0.02-0.13)	0.131
60 years old and above						
Excellent & Very good Hearing (reference group)						
Good hearing	1.41 (1.12–1.79)	0.004	1.38 (1.07–1.79)	0.014	0.12 (0.05–0.20)	0.002

[a] Time to first hospitalization was determined using Cox proportional hazards regression, controlling for demographic characteristics (age, gender, residency, education, marriage, occupation), chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular disease), smoking history and hearing aid use.

[b] Annual number of hospitalizations in participants with at least one hospitalization was determined using negative binomial regression, controlling for demographic characteristics (age, gender, residency, education, marriage, occupation), chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular disease), smoking history and hearing aid use.

[c] Mean duration of last-time hospitalization was determined using lognormal regression, controlling for demographic characteristics (age, gender, residency, education, marriage, occupation), chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular disease), smoking history and hearing aid use.

CI confidence interval.

*P < 0.05,**P < 0.01,***P < 0.001

Hearing Status	Time to First Hospitalization [a]		Annual number of hospitalizations [b]		Mean Duration of Last-time Hospitalization [c]	
	Hazard Ratio (95% CI)	P-Value	Incidence Rate Ratio (95% CI)	P-Value	Factor Change (95% CI)	P-Value
Fair hearing	1.58 (1.26–1.97)	< 0.001	1.61 (1.27–2.05)	< 0.001	0.16 (0.09–0.23)	< 0.001
Poor hearing	1.69 (1.33–2.14)	< 0.001	1.68 (1.28–2.20)	< 0.001	0.19 (0.11–0.27)	< 0.001

[a] Time to first hospitalization was determined using Cox proportional hazards regression, controlling for demographic characteristics (age, gender, residency, education, marriage, occupation), chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular disease), smoking history and hearing aid use.

[b] Annual number of hospitalizations in participants with at least one hospitalization was determined using negative binomial regression, controlling for demographic characteristics (age, gender, residency, education, marriage, occupation), chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular disease), smoking history and hearing aid use.

[c] Mean duration of last-time hospitalization was determined using lognormal regression, controlling for demographic characteristics (age, gender, residency, education, marriage, occupation), chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular disease), smoking history and hearing aid use.

CI confidence interval.

*P < 0.05,**P < 0.01,***P < 0.001

For older adults aged 60 years old and above, good hearing status was significantly associated with longer time to incident (first) hospitalization in the Cox model. Compared with excellent & very good hearing, good hearing (hazard ratio (HR) = 1.41, 95% CI = 1.12–1.79), fair hearing (HR = 1.58, 95% CI = 1.26–1.97) and poor hearing (HR = 1.69, 95% CI = 1.33–2.14) were associated with longer time to incident (first) hospitalization (Table 3). While for the middle-aged adults aged 45–59 years old, there was no significant association between hearing status and time to incident (first) hospitalization.

Annual Number of Hospitalizations

The association between self-rated hearing status and annual number of hospitalizations was next explored using hurdle negative binomial regression, adjusting for demographic characteristics, e.g. age, gender, residency, education, marriage, occupation, chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular diseases), smoking history and hearing aid use. For individuals aged 60 years old and above with at least one hospitalization, there was a gradient greater annual number of hospitalizations for those with good hearing (incident rate ratio (IRR) = 1.38, 95% CI = 1.07–1.79), fair hearing (IRR = 1.61, 95% CI = 1.27–2.05), and poor hearing (HR = 1.68, 95% CI = 1.28–2.20), compared with those with excellent & very good hearing (Table 3).

Duration of Last-time Hospitalization

A lognormal model was used to investigate the association between self-rated hearing status and mean duration of last-time hospitalization, adjusting for demographic characteristics, e.g. age, gender, residency, education, marriage, occupation, chronic diseases (hypertension, diabetes mellitus, stroke, cardiovascular diseases), smoking history and hearing aid use. For individuals aged 45–59 years old, there was no significant difference in duration of last-time hospitalization between hearing status gradients. For those aged 60 years old and above, the mean duration of last-time hospitalization was significantly different between individuals with excellent & very good hearing and those with other hearing status (good hearing factor change in mean duration of last-time hospitalization = 0.12, 95% CI = 0.05–0.20; fair hearing factor change = 0.16, 95% CI = 0.09–0.23; poor hearing factor change = 0.19, 95% CI = 0.11–0.27) (Table 3).

Hearing Aid Use

Hearing aid use was included as a covariate in models to determine whether it was associated with risk of hospitalization. The results showed that it was not associated with time to incident hospitalization in Cox models (HR of hearing aid use = 0.89, 95% CI = 0.52–1.54), or annual number of hospitalizations in negative binomial models (IRR = 0.70, 95% CI = 0.41–1.19), nor was it associated with shorter mean duration of last-time hospitalization in fully adjusted lognormal models (factor change=-0.12, 95% CI=-0.31-0.07).

Discussion

Hearing is one of the basic means of perception and communication which is closely related with quality of life and public health [22]. Despite the importance of hearing in everyday life, hearing impairment is often unrecognized and undertreated, thus resulting in a growing number of people suffering from hearing impairment. Moreover, the hearing impairment risk increases rapidly with age, and the prevalence rate of older adults is significantly higher than other groups [23]. The World Health Organization pointed out that in 2012, about one-third of the world's older adults aged 65 and above had moderate or above hearing impairment [24]. As the global aging intensifies, hearing impairment is becoming an even more serious public health problem [25]. The 2015 Global Burden of Disease Study further found that hearing impairment had become the second chronic disease threatening human health [26].

In this study, we observed that 54.46% of the total participants reported having fair or poor hearing, which occupied a large proportion of the participants. Besides, hearing impairment in community-dwelling Chinese older adults was found to be independently associated with higher risk of hospitalization. In the age group of 60 and above, compared with participants with excellent or very good hearing, those with good, fair and poor hearing had a shorter time to incident (first) hospitalization (HR = 1.41, 1.58, 1.69, respectively), a greater annual number of hospitalizations (IRR = 1.38, 1.61, 1.68, respectively) and a longer mean last-time duration of hospitalization (factor change = 0.12, 0.16, 0.19, respectively). We did not find a significant association between hearing status and risk of hospitalization among middle-aged Chinese adults, probably due to their relatively better health status. These findings suggest that gradient hearing

impairment, which is highly prevalent but undertreated, is a significant risk factor for hospitalization in older adults.

What we have found are in some way consistent with previous studies that hearing impairment is associated with greater utilization of healthcare resources. Hearing impaired older adults used significantly more health services than people with normal hearing [27–30]. Previous researches have also further demonstrated the relationship between hearing status and hospitalization [13, 14]. A study examining civilian, noninstitutionalized US population aged over 70 years old found that hearing loss was associated with higher odds of any hospitalization and higher odds of more hospitalizations for the increase in hearing thresholds, after adjusting for demographic characteristics and cardiovascular comorbidities [13]. For those aged 70–79 years old, the same result was derived that hearing-impaired older adults experienced a greater incidence and annual number of hospitalizations than those with normal hearing [14]. This may imply that encouraging and promoting the access to hearing rehabilitation services would be effective measures in reducing the risk of hospitalization and burden of diseases.

We speculate that some possible mechanisms may account for the associations between hearing status gradients and risk of hospitalization. Common risk factors or pathological processes such as inflammation [31] or microvascular disease [32, 33] are likely to lead to poor hearing and risk of hospitalization. And social isolation may play an intermediary role in the relationship between hearing status gradients and hospitalization risk, as it can be a potential sequela of hearing impairment, reducing people's efficacy and perceived self-worth, aggravating depression and does harm to physical and mental health [34–37]. Hearing impairment may also lead to poorer oral literacy, so patients are not able to effectively communicate with physicians and care provider [38–41]. It has been proved that oral literacy is an independent risk factor for hospitalization and a key determinant of health in older adults [42, 43]. Hearing impairment has also been found to be strongly associated with poor cognition, interfering knowledge acquisition and understanding, which may further add to hospitalization risk [44–46]. Besides, those with worse hearing status showed lower rate of wearing hearing aids. But due to lack of more detailed information on the time and frequency of hearing aid use or other auxiliary equipment, we were unable to draw more specific conclusion about the effects of hearing aids.

In this study, due to the limitations of survey data, we lacked information about standardized audiometric assessments in individual level and had to apply self-rated hearing status in this study. Although prior studies have noted that a single-item question about an individual's hearing ability is moderately useful and valid to assess hearing loss and can be used for a population-based study, we have to admit self-rated hearing should not be considered an adequate substitute and its validity has not been evaluated among Chinese middle-aged and older adults [47–49]. The strengths are that we employed the method of prospective cohort study to determine that hearing status gradients could be associated with risk of hospitalization. And hospitalization details were supported by hospital records and other documents objectively, ensuring fidelity of hospitalization information. Moreover, we have taken potential broader implications of these observed associations into account and tried to figure the mechanism for the associations between hearing status gradients and risk of hospitalization.

Conclusions

Preventable hospitalizations are a significant driver of growing healthcare costs in China. This study has demonstrated that highly prevalent hearing impairment in older adults is independently associated with shorter time to incident (first) hospitalization, larger annual rate and longer duration of hospitalization. Further study is required to determine whether hearing rehabilitation could mitigate the role of hearing status gradients in risk of hospitalization in older adults.

Abbreviations

CHARLS: China Health and Retirement Longitudinal Study; CI: Confidence Interval; HR: Hazard Ratio; IRR: Incidence Rate Ratio; ANOVA: analysis of variance.

Declarations

Ethics approval and consent to participate

The ethics application for collecting data on human subjects was approved and updated annually by Peking University's Institutional Review Board. All participants provided written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The data supporting the conclusion of this article are includes within the article. Any queries regarding these data may be directed to the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

XY analyzed and interpreted the data. DZ and PH provided statistical analysis and critical revision. All authors read and approved the final manuscript.

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Figures

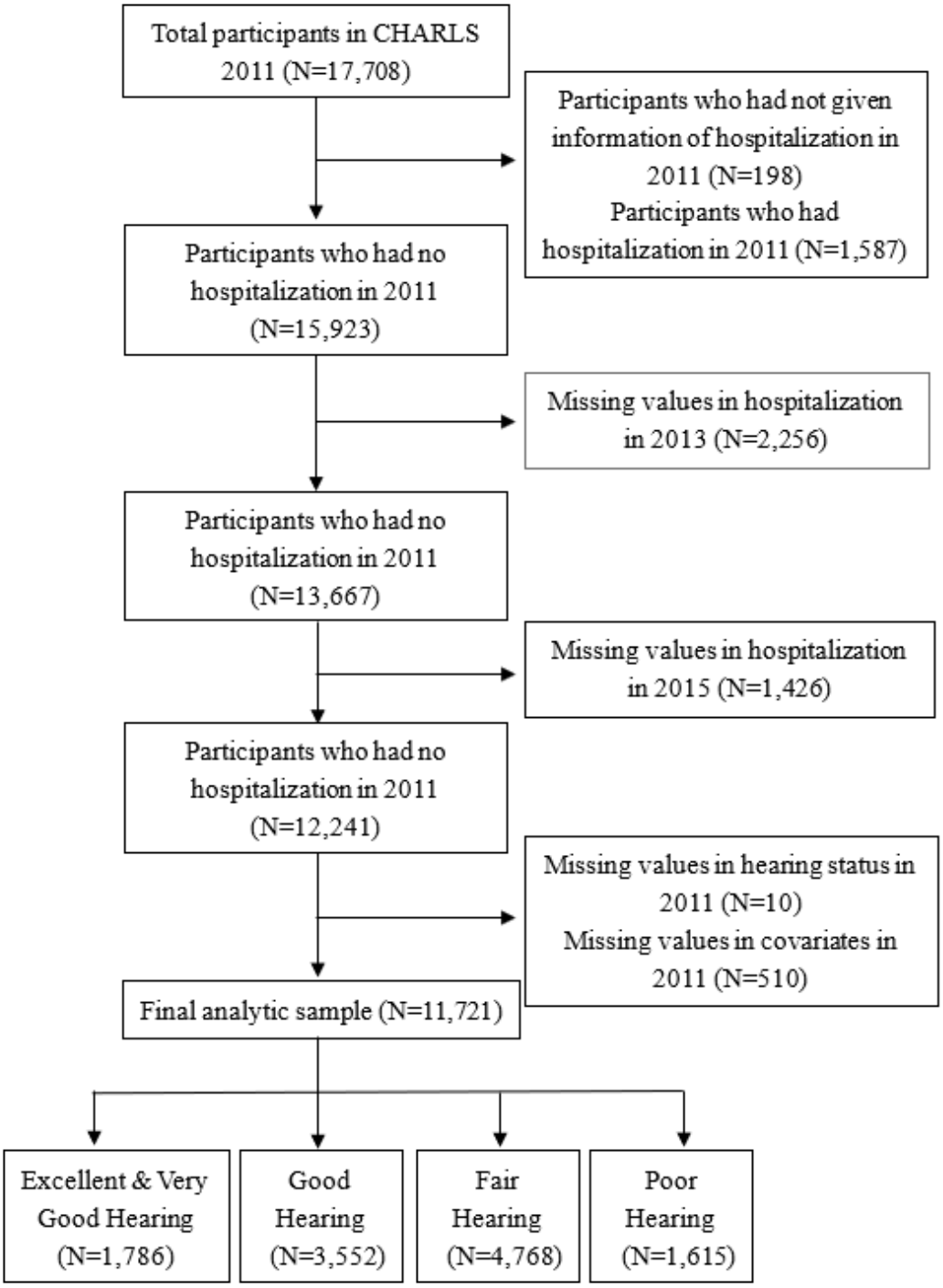

Figure 1

Flowchart of the study sample

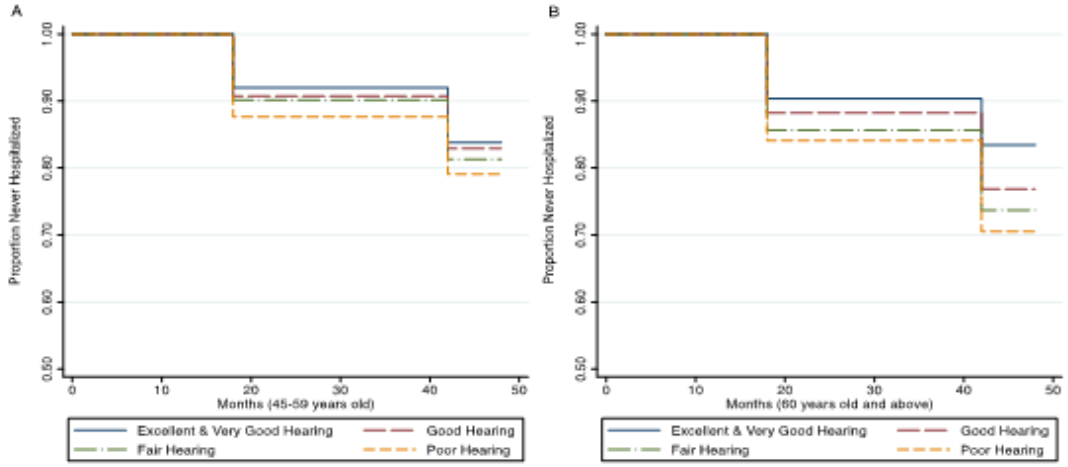

Figure 2

Kaplan-Meier survivor estimate for the proportion never hospitalized, 2011-2015

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