

# Hearing Status of Low-Income, Middle-Aged and Elderly Women in Northern China: A Population-Based, Cross-Sectional Study

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**Objective:** Hearing impairment (HI) has become one of the most common causes of disability worldwide. To date, few studies have examined the hearing of women in these frequently rural regions. Thus, we explored the HI prevalence and risk factors among low-income, middle-aged, and elderly women in Tianjin, China.

**Methods:** Between October and November 2013, female residents aged  $\geq 45$  years of rural Tianjin, China were recruited into the study. The participants completed questionnaire surveys, physical examinations, and hearing tests. The hearing at frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz was used to analyze the hearing characteristics of specific frequency bands, and HI was defined as the better ear pure tone averages (PTA)  $> 25$  dB HL.

**Results:** Among the 1416 participants, the prevalence of HI was 46.0%. Among those aged 45–54-years, most (65.3%) demonstrated normal hearing; in other age groups, slight HI accounted for the largest proportions of individuals. Compared with women who did not drink, the odds ratio (OR) of HI among women who consumed alcohol was 4.2 (95% confidence interval [CI]: 1.844–9.574;  $P = 0.001$ ). Compared with pre-menopausal women, the OR of HI among postmenopausal women was 1.8 (95% CI: 1.261–2.667;  $P = 0.001$ ). Further, each 1-year increase in age in women resulted in a 7.1% increase in HI risk ( $P < 0.001$ ).

**Conclusion:** The burden of HI among women is heavy in rural northern China, especially among those who experienced menopause. Additionally, the results suggest that to further reduce the risk of developing HI, women in rural areas should stop consuming alcohol. The problem of HI among women in rural areas should be taken seriously; moreover, the measures implemented to prevent HI in high-risk women should be strengthened.

**Keywords:** hearing impairment, women, risk factors, epidemiology, population-based study

## Introduction

Globally, hearing impairment (HI) has become the third most common cause of disability in the elderly.<sup>1,2</sup> As an age-related disease, HI accounts for almost 5% of the total years lived with disability<sup>3</sup> and imposes a great burden on healthcare systems due to its long-term social, functional, and psychological complications.<sup>4</sup> In 2018, there were approximately 466 million individuals with HI worldwide,<sup>5</sup> with approximately 90% of those living in low- and middle-income countries.<sup>6</sup> There are differences in hearing between men and women.<sup>7</sup> In low-income countries or regions, women frequently have a lower social status than men. Therefore, more attention should be paid to hearing function in women.

Previous studies indicated that the risk of HI is higher among postmenopausal women.<sup>8,9</sup> Estrogen can be produced by auditory neurons,<sup>10</sup> which can directly affect neurotransmission and indirectly affect cochlear blood flow.<sup>11,12</sup> Regardless of the mechanism, few studies have focused on HI in rural women. Further, relevant population studies from China have not reported on the hearing abilities of rural women nor on the impact of menopause on the hearing of this population.

Thus, this study explored the hearing status of middle-aged and elderly women in rural Tianjin, China and investigated factors affecting HI prevalence among these women.

## Methods

### Study Population

This population-based study was performed between September and November 2013 in rural Tianjin, China. The participants were recruited from the Tianjin Brain Study, which is a chronic disease surveillance study of low-income individuals, monitoring the chronic disease prevalence of long-term residents in the area since 1991. In brief, the participants were recruited from 18 administrative villages in rural Tianjin, China. Most (95%) residents were low-income farmers with an annual per capita income of <\$100 US dollars (USD) in 1991 and <\$2500 USD in 2018.<sup>13</sup> All women aged over 45 years who live in Yangjinzhuang Town, Jizhou District, Tianjin were qualified in this study. Those women who worked out of Tianjin, or were disability due to diseases, were excluded in this study.

### Information Collection and Risk Factor Definition

The data for this study were obtained and recorded by trained researchers using face-to-face interviews. Demographic information, including participant sex, age, and educational level, were captured using pre-designed questionnaires. The participants were grouped into four age categories: 45–54 years, 55–64 years, 65–74 years, and  $\geq 75$  years. Participant educational levels were classified into three groups, based on their years of formal education: illiterate (0 years), 1–6 years, and  $>6$  years.

Individual and family medical histories, including information regarding hypertension, diabetes mellitus (DM), stroke, and coronary heart disease (CHD), were obtained from participant self-reports or existing medical records. Cigarette smoking was defined as smoking  $>1$

cigarette/day for  $\geq 1$  year; participants were categorized as non-smokers, current smokers, or previous smokers. Alcohol consumption was defined as drinking one alcoholic beverage/week for  $\geq 1$  year; participants were categorized as non-drinkers, past drinkers, or current drinkers. Data regarding eating habits and menopause details were obtained through participant self-reports.

### Physical Examination

Systolic blood pressure (SBP), diastolic blood pressure (DBP), height, weight, waist circumference, and hip circumference measurements were performed by local general practitioners. Further, fasting levels of blood glucose (FBG), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were determined within 2 hours after the blood sample was taken at the Jizhou People's Hospital (Tianjin, China), which has an international standard blood laboratory with reliable test results. Body mass index (BMI) was calculated as the individual's weight (kg) divided by the square of their height ( $m^2$ ); weight classifications were based on BMI (low-weight,  $<18.5$   $kg/m^2$ ; normal,  $18.5$ – $23.9$   $kg/m^2$ ; overweight,  $24.0$ – $27.9$   $kg/m^2$ ; and obese,  $\geq 28.0$   $kg/m^2$ ).<sup>14</sup>

### Hearing Test

Professional otolaryngology medical technicians performed bilateral otoscopy and audiometry evaluations on each participant in a quiet, soundproof room; participants with suspected HI were referred to audiologists for final diagnoses. Air conduction hearing thresholds at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz frequencies were obtained using a Denmark Xeta Audiometer (EN60645-1, type 3). When measuring the hearing of one ear, masking was used on the other ear. Hearing at frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz was used to analyze the hearing characteristics of specific frequency bands.

Pure tone averages (PTAs), representing speech frequencies and reported as decibels of hearing level (dB HL), were calculated using the average audiometric thresholds of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz for the bilateral ears. HI was defined as the better PTA  $>25$  dB HL; and HI was stratified using the bilateral PTA results as slight ( $>25$  and  $\leq 40$  dB HL), moderate ( $>40$  and  $\leq 60$  dB HL), severe ( $>60$  and  $\leq 80$  dB HL), and severe to profound ( $>80$  dB HL).<sup>15</sup> HI was defined based on the better hearing ear (using PTA).

## Statistical Analyses

Continuous variables (age, BMI, SBP, DBP, WHR, FBG, TC, TG, HDL-C, LDL-C, and PTA) are presented as means and standard deviations; between-group comparisons of these values were performed using Student's *t*-tests. Categorical variables of age group; education group; BMI group; smoking history; alcohol consumption history; and previous histories of hypertension, DM, stroke, and CHD are presented as number of patients and prevalence. The between-group comparisons for categorical variables were performed using the chi-squared test. Binary logistic regression was chosen to evaluate the association between HI and its potential risk factors. In the multivariate analysis, we selected variables that had *P* values <0.05 in two-tailed tests in univariate analysis. Finally, the dependent variable was binary (HI or normal hearing), and the independent variables were education group, alcohol consumption history, menopause history, age, and SBP. Moreover, multivariate analysis results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). All analyses were conducted using SPSS for Windows (version 25.0; SPSS, Chicago, IL, USA); *P* < 0.05 was considered statistically significant.

## Results

Total of 1881 participants were recruited among 2452 permanent women after excluded those worked outside residents (*n*=200), disability due to diseases (*n*=59). Of these, 1416 women finished the hearing test. As menopausal history was included in the multivariate analysis, 81 (5.7%) women with missing menstrual history data were excluded from the model. Finally, 1335 participants were assessed the prevalence and risk factors of HI.

## Patient Demographics

Of the 1416 included women, 652 (46.0%) demonstrated HI, 617 (44.4%) were illiterate, 588 (41.5%) had hypertension, 143 (10.1%) had DM, and 220 (15.6%) had CHD (Table 1).

## Factors Associated with HI in the Univariate Analysis

The prevalence of HI increased significantly with increasing age, but decreased with increasing levels of education (both, *P* < 0.001). The HI prevalence was higher among women who consumed alcohol than among those who did not and among menopausal women than among premenopausal women (both, *P* < 0.001). The mean menopausal

age and DBP were significantly lower in participants with HI than in those without HI (both, *P* < 0.05); however, mean SBP was significantly higher in participants with HI (*P* = 0.001) (Table 1).

## Hearing Test Results, by Age

With increasing age, the percentage of participants with normal hearing declined; the prevalence of moderate, severe, and extremely severe HI was significantly higher in the older age groups than in the 45–54-years-old group (all, *P* < 0.001). In addition to right ear HI at 500 Hz, the percentage of patients with bilateral HI at 1000 Hz, 2000 Hz, 4000 Hz, and PTA increased with age (all, *P* < 0.001) (Table 2).

## Factors Associated with HI in the Multivariate Analysis

After adjusting for education and SBP, older age, alcohol consumption, and menopausal history were independent risk factors for HI (all, *P* < 0.05). The prevalence of HI was 4.2-fold higher among women who consumed alcohol than among women who never did so (95% CI: 1.84–9.556; *P* = 0.001). Compared with premenopausal women, the OR of HI among postmenopausal women was 1.8 (95% CI: 1.261–2.677; *P* = 0.001); each 1-year increase in age resulted in 7.1% decrease in the risk of HI (*P* < 0.001) (Table 3).

## Discussion

This large-scale population study explored the hearing status of women aged ≥45 years who resided in a rural area of northern China. The HI prevalence among the study population was 46.0% and increased with increasing age. In addition, the OR for developing HI was 4.2-fold higher for women who consumed alcohol than for those who did not. Postmenopausal women were 1.8 times more likely to develop HI than were premenopausal women.

A previous study reported that in the United States, the prevalence of HI was 28.5% among women ≥55 years old.<sup>16</sup> Similarly, a study conducted in the Netherlands showed that the prevalence of HI was 29% among female participants ≥65 years old.<sup>17</sup> In Finland, a population-based HI study involving 55–64-year-old adults reported that the prevalence of HI was 18.4%.<sup>18</sup> However, the prevalence of HI among ≥65 years old women in Brazil was 39.4%,<sup>19</sup> and the total prevalence of HI was 38.8% in rural India,<sup>20</sup> which was much higher than that in

**Table 1** Associated Factors of Hearing Impairment in the Univariate Analysis

Category	Total	Normal Hearing	Hearing Impairment	P
Total:	1416	764 (54.0)	652 (46.0)	
Age group, n (%)				<0.001
45–54 years	123 (8.7)	25 (3.3)	98 (15.0)	
55–64 years	325 (23.0)	139 (18.2)	186 (28.5)	
65–74 years	591 (41.7)	354 (46.3)	237 (36.3)	
≥75 years	377 (26.6)	246 (32.2)	131 (20.1)	
Education*, n (%)				<0.001
0 years	617 (44.4)	293 (39.1)	324 (50.5)	
1–6 years	399 (28.7)	214 (28.6)	185 (28.8)	
> 6 years	275 (19.8)	242 (32.3)	133 (20.7)	
Menopause*, n (%)				<0.001
No	215 (16.1)	134 (62.3)	81 (37.7)	
Yes	1120 (83.9)	589 (52.3)	531 (47.4)	
Smoking status, n (%)				0.372
Never smoking	1356 (95.8)	735 (54.2)	621 (45.8)	
Now or ever smoking	60 (4.2)	29 (48.3)	31 (51.7)	
Alcohol consumption, n (%)				<0.001
Never drinking	1380 (97.4)	755 (54.7)	625 (45.3)	
Now or ever drinking	36 (2.6)	9 (25.0)	27 (75.0)	
Stroke, n (%)				0.999
No	1340 (94.6)	723 (54)	617 (46)	
Yes	76 (5.4)	41 (53.9)	35 (46.1)	
Hypertension, n (%)				0.152
No	828 (58.5)	460 (55.6)	368 (44.4)	
Yes	588 (41.5)	304 (51.7)	284 (48.3)	
High-carbohydrate diet, n (%)				0.081
No	1376 (97.2)	737 (53.6)	639 (46.4)	
Yes	40 (2.8)	27 (67.5)	13 (32.5)	
Diabetes, n (%)				0.205
No	1273 (89.9)	694 (90.8)	579 (88.8)	
Yes	143 (10.1)	70 (9.2)	73 (11.2)	
CHD, n (%)				0.085
No	1196 (84.4)	657 (54.9)	539 (45.1)	
Yes	220 (15.6)	107 (48.6)	113 (51.4)	
BMI, n (%)				0.173
Low-weight	265 (4.6)	142 (53.6)	123 (46.4)	
Normal	561 (39.6)	317 (56.5)	244 (43.5)	
Overweight	42 (3.0)	17 (40.5)	25 (59.5)	
Obesity, n (%)	548 (38.7)	288 (52.6)	260 (47.4)	
Age, means (SD), years	60.83 (9.04)	58.69 (7.60)	63.34 (9.92)	<0.001
BMI, means (SD), Kg/m <sup>2</sup>	24.91 (3.67)	24.99 (3.50)	24.82 (3.85)	0.405
WHR, means (SD)	0.90 (0.26)	0.89 (0.06)	0.91 (0.38)	0.191
Menopause age, mmol/L	49.18 (4.11)	49.44 (3.82)	48.89 (4.40)	0.025

(Continued)

**Table 1** (Continued).

Category	Total	Normal Hearing	Hearing Impairment	P
FBG, means (SD), mmol/L	5.54 (1.81)	5.5 (1.76)	5.58 (1.86)	0.373
TC, means (SD), mmol/L	4.78 (0.94)	4.75 (0.93)	4.82 (0.95)	0.143
TG, means (SD), mmol/L	1.58 (0.97)	1.59 (0.96)	1.57 (0.97)	0.756
HDL-C, means (SD), mmol/L	1.40 (0.46)	1.39 (0.43)	1.41 (0.49)	0.302
LDL-C, means (SD), mmol/L	2.71 (0.85)	2.69 (0.84)	2.75 (0.86)	0.180
SBP, means (SD), mmHg	151.57 (24.04)	149.57 (23.73)	153.9 (24.22)	0.001
DBP, means (SD), mmHg	90.55 (12.36)	91.21 (12.12)	89.77 (12.59)	0.030

Note: \*Presented data with missing case for education (n=25) and menopause (n=81).

Abbreviations: SD, standard deviation; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; FBG, fasting blood glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol.

**Table 2** Hearing Test Results and Hearing Grading of Women by Age Groups

Category	45–54 Years	55–64 Years	65–74 Years	≥75 Years	P
Hearing classification, n (%):					<0.001
Normal	246 (65.3)	354 (59.9)	139 (42.8)	25 (20.3)	
Slight	126 (33.4)	210 (35.5)	156 (48.0)	61 (49.6)	
Moderate	5 (1.3)	26 (4.4)	27 (8.3)	35 (28.5)	
Severe	–	1 (0.2)	3 (0.9)	2 (1.6)	
Hearing test (dBHL), means(SD):					
L 500 Hz	28.16 (9.86)	28.67 (9.85)	31.48 (12.15)	35.73 (14.48)	<0.001
L 1000 Hz	27.37 (9.59)	28.64 (10.12)	32.08 (13.24)	36.79 (13.72)	<0.001
L 2000 Hz	26.29 (8.19)	27.64 (9.33)	31.92 (13.08)	37.52 (15.11)	<0.001
L 4000 Hz	26.59 (8.39)	29.85 (23.90)	34.23 (15.39)	44.76 (18.38)	<0.001
R 500 Hz	27.32 (8.64)	27.78 (10.40)	41.58 (194.56)	37.64 (31.92)	0.057
R 1000 Hz	27.27 (8.27)	28.47 (11.66)	31.58 (13.16)	37.44 (13.90)	<0.001
R 2000 Hz	25.74 (7.45)	27.32 (11.36)	31.72 (17.52)	38.66 (14.40)	<0.001
R 4000 Hz	26.21 (8.79)	28.69 (12.00)	33.86 (15.15)	44.02 (17.40)	<0.001
RPTA	26.63 (7.47)	28.06 (10.49)	34.69 (50.36)	39.44 (14.63)	<0.001
LPTA	27.10 (8.35)	28.70 (10.66)	32.43 (12.40)	38.70 (14.07)	<0.001

developed countries. Previous studies have indicated that the level of economic development affects the prevalence of HI.<sup>16,17</sup> Socioeconomic status has been confirmed to be a main factor predicting HI prevalence.<sup>4,21–23</sup> From previous studies, it can be found that the prevalence of HI in developed countries is much lower than in developing countries.<sup>8,17</sup> Moreover, study populations from different regions have different living and eating habits that need to be considered more in depth to determine their effect on hearing. Thus, this may explain why the prevalence of HI among the rural women reported in this study was higher than that reported in more developed areas.

Between 1980 and 2010, as the global population has aged, the prevalence of HI in developed countries has doubled.<sup>24</sup> Previous studies have indicated that HI is an age-related disease.<sup>25–27</sup> Similarly, in this study, the values of the pure-tone hearing tests increased with increasing age, and the risk of developing HI also increased with age. Prior studies have shown that mitochondrial DNA mutations<sup>28</sup> and oxidative damage<sup>29</sup> are mechanisms contributing to HI in aging people.

Controversy exists about the relationship between alcohol consumption and HI. One previous study reported that drinking increases the risk of HI,<sup>30</sup> while others either

**Table 3** Adjusted OR (95% CI) of Risk Factors Association with Hearing Impairment

Risk Factors	OR (95% CI)	P
Education groups:		
0 years	1.241 (0.910, 1.692)	0.172
1–6 years	1.184 (0.863, 1.625)	0.295
> 6 years	1.00	–
Alcohol consumption		
No	1.00	–
Yes	4.202 (1.844, 9.574)	0.001
Menopause history		
No	1.00	–
Yes	1.834 (1.261, 2.667)	0.001
Age	1.071 (1.052, 1.090)	< 0.001
SBP	1.002 (0.997, 1.007)	0.504

indicated a U-shaped association between alcohol consumption and HI<sup>31,32</sup> or did not find a significant association.<sup>33,34</sup> The present study showed that the prevalence of HI was significantly higher among women who consumed alcohol than among those who never consumed alcohol. The mechanism for alcohol consumption's effect on hearing is unclear, and further research is needed.

The relationship between menopause and HI is also unclear. Although some studies have shown that ovarian hormones, including estrogen, may have a negative effect on the cochlear nerve,<sup>35</sup> most studies have reported that estrogen exerts a protective effect on hearing.<sup>36,37</sup> Previous studies have also demonstrated the expression of estrogen in the inner ear.<sup>10</sup> Moreover, estrogen can be produced by auditory neurons per se and directly affects neurotransmission.<sup>11</sup> In addition, estrogen has also been shown to indirectly affect cochlear blood flow, which may play a role in auditory function.<sup>12</sup> In this study, compared with premenopausal women, the prevalence of HI increased among postmenopausal women. The mechanism by which menopause may impact HI remains unclear, and more research is needed to strengthen the conclusions.

The impact of blood pressure on HI is also inconclusive. Some studies have indicated that hypertension is a risk factor for HI,<sup>38,39</sup> while another study reported no significant relationship between SBP and HI.<sup>40</sup> Another study showed that the relationship between age-related hearing loss and blood pressure differs according to age. There is no correlation between blood pressure and hearing in women aged 70–75 years, but in women aged over

79 years, there is a high correlation between SBP and low-frequency hearing loss.<sup>41</sup> In the present study, a significant relationship between SBP and HI was not observed. Further, the mechanism by which blood pressure may impact HI remains unclear. High blood pressure may harm hearing due to pressure-induced microvascular atherosclerosis, which affects the auditory blood flow and causes hearing loss.<sup>36</sup> Long-term follow-up studies are required to validate this relationship.

This study has some limitations. First, this was a single-center study and a multi-center study is needed to verify the present results. Second, due to the lack of the exact amount of alcohol consumed within a certain period, we used categorical variables to evaluate the impact of alcohol consumption on HI. The relationship between the amount of alcohol consumed and any associated HI needs further exploration. Third, this study did not employ otoscopy and tympanometry test on patients because the conditions of the study were limited. In the follow-up, we will implement more rigorous hearing-related testing. Finally, as this was a cross-sectional study, causal relationships between the risk factors and HI cannot be determined; follow-up studies involving similar populations are required.

## Conclusion

This was the first large-scale population study to investigate the hearing status of rural women  $\geq 45$  years old in northern China. There is a substantial burden of HI among women in rural northern China. Alcohol consumption and older age appear to increase the prevalence of HI. Moreover, postmenopausal women have a significantly increased prevalence of HI. Therefore, targeted health guidance should be formulated regarding the factors influencing HI to reduce the prevalence of HI among women residing in rural areas of northern China; in particular, attention should be given to postmenopausal women.

## Abbreviations

HI, hearing impairment; DM, diabetes mellitus; CHD, coronary heart disease; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting levels of blood glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; BMI, body mass index; PTA, pure tone average; SD, standard deviation; OR, odds ratio.

## Data Sharing Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Ethics Approval and Informed Consent

The study was approved by the ethics committee of Tianjin Medical University General Hospital; informed consent was obtained from each participant. This study was conducted in accordance with the Declaration of Helsinki.

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## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors declare that they have no competing interests.

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