Clinical Interventions in Aging

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ORIGINAL RESEARCH

Multidimensional Risk Factors of Age-Related Hearing Loss Among Malaysian Community-Dwelling Older Adults

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Purpose: This study evaluates the prevalence of and the multidimensional risk factors associated with age-related hearing loss (ARHL) among community-dwelling older adults in Malaysia.

Patients and Methods: A total of 253 participants aged 60 years and above participated in this cross-sectional study. The participants were subjected to pure tone audiometric assessment. The hearing threshold was calculated for the better ear and classified into pure-tone average (PTA) for the octave frequencies from 0.5 to 4 kHz and high-frequency pure-tone average (HFA) for the octave from 2 to 8kHz. Then, the risk factors associated with PTA hearing loss (HL) and HFAHL were identified by using multivariate logistic regression analysis.

Results: The prevalence of ARHL based on PTA and HFA among the community-dwelling older adults was 75.5% and 83.0%, respectively. Following multifactorial adjustments, being older (OR: 1.239; 95% CI: 1.062–1.445), having higher waist circumference (OR: 1.158; 95% CI: 1.015–1.322), lower intake of niacin (OR: 0.909; 95% CI: 0.831–0.988) and potassium (OR: 0.998; 95% CI: 0.996–1.000), and scoring lower in RAVLT T5 (OR: 0.905; 95% CI: 0.838–0.978) were identified as the risk factors of PTAHL. Meanwhile, being older (OR: 1.117; 95% CI: 1.003–1.244), higher intake of carbohydrate (OR: 1.018; 95% CI: 1.006–1.030), lower intake of potassium (OR: 0.998; 95% CI: 0.997–0.999), and lower scores on the RAVLT T5 (OR: 0.922; 95% CI: 0.874–0.973) were associated with increased risk of having HFAHL.

Conclusion: Increasing age, having higher waist circumference, lower intake of niacin and potassium, higher intake of carbohydrates and having lower RAVLT T5 score were associated with increased risk of ARHL. Modifying these risk factors may be beneficial in preventive and management strategies of ARHL among older persons.

Keywords: cognitive function, dietary intake, hearing loss, older adults, prevalence, risk factors

Introduction

Age-related hearing loss (ARHL) is an age-related degenerative disease characterized by progressive symmetrical sensorineural hearing loss (HL) predominantly at higher frequencies.[1] Approximately 1.5 billion people experience a certain degree of HL worldwide, with more than 42% of them being older adults aged 60 years and above.[2] It is reported that over 65% of individuals older than 60 years old have HL, and the prevalence increases exponentially with age among the older populations.[3] The prevalence of ARHL is expected to increase dramatically due

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Received: 21 September 2021
Accepted: 19 November 2021
Published: 8 December 2021

to the increasing aging population worldwide, as observed in the current trend of the global population shift.[2]

The underlying causes of ARHL are complex and multifactorial. Its development and progression could be attributed to predisposing genetic and biological risk factors, comorbidities, lifestyle behaviors and environmental insults.[1,4] Predisposing genetic factors play a crucial role in determining the onset and severity of ARHL. Meanwhile, men are more likely to develop ARHL than women of the same age, probably due to a higher risk of exposure to noise or other environmental risk factors.[2] Individuals with certain health conditions such as cardiovascular diseases, diabetes and renal diseases are at greater risk of ARHL.[4] The use of ototoxic drugs, constant exposure to occupational hazards such as noise and chemicals, as well as practicing unhealthy lifestyle habits (eg, smoking, excessive intake of alcohol, unhealthy eating habits, nutritional deficiency and exposure to excessive loudness in recreational settings) appeared as the common risk factors of such sensory deficit.[1,4] All these risk factors can initiate and exacerbate the progression of ARHL independently or synergistically.

ARHL is the third largest cause of years lived with disability (YLDs) in 2019 and the leading cause of YLDs for older adults over 70 years.[3] Due to its high prevalence globally, ARHL posts significant economic impacts on society.[5] Moreover, unaddressed HL among older adults may lead to cognitive, physical and psychosocial problems such as social isolation, functional loss, depression, cognitive impairment and physical frailty.[1,4] Early screening for ARHL and the use of hearing aids have been reported to mitigate the adverse effects and improve the quality of life of those affected. However, the effectiveness of such interventional approaches is limited by several factors, including lack of accessibility to related healthcare facilities providing specialized hearing care, stigma and inability to afford hearing aids.[5] Identification of risk factors, especially modifiable risk factors (eg, lifestyle habits and environmental insults), may help plan and develop preventive strategies to reduce the progression and severity of ARHL. However, study focus on ARHL is limited in Malaysia. The National Ear and Hearing Disorders Survey completed in 2005 found that 69.9% of older adults aged 60 years and above have HL.[6] While the study reported on demographic trends of HL, it did not provide a detailed investigation of modifiable risk factors of HL. Hence, the main objective of this study was to determine the multidimensional risk factors of ARHL among community-dwelling older adults in Malaysia.

Materials and Methods

Study Cohort

This study was part of a prospective population-based study on aging [Long-term Research Grant Scheme – Towards Useful Ageing (LRGS-TUA)]. The data were collected from the first wave of the LRGS-TUA study conducted in the year 2013. The older adults aged 60 and above were recruited through a stratified random sampling method from four different states in Malaysia, which were Selangor (central part of Malaysia), Perak (north-west), Kelantan (north-east) and Johor (southern part). The audiometric assessment data, however, was only available for participants from Selangor. A total of 573 older adults fulfilled the inclusion criteria and agreed to participate. However, only 253 participants (44.2%) completed all the testing were included in this study. The sampling method, inclusion criteria and exclusion criteria for this study were described in detail by Shahar et al.[7]

Ethics Approval and Informed Consent

This study was approved by the Medical Research and Ethics Committee of Universiti Kebangsaan Malaysia (UKM 1.5.3.5/244/NN-060-2013) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from the participants before their participation.

Data Collection

Data on socio-demographic, medical history, dietary status, cognitive function, psychosocial and functional status of the participants were obtained by trained field workers through face-to-face interviews using standardized questionnaires.[7] The data on anthropometric, body composition, blood pressure, physical fitness, biochemical and audiometric were assessed using protocols as described by Shahar et al.[7]

Socio-Demographic Data and Medical History

The information obtained included the age, sex, ethnicity, smoking and alcohol drinking habits, years of education and self-reported medical history (hypertension, hypercholesterolemia, diabetes mellitus, cardiovascular disease and tinnitus).

Anthropometric, Body Composition and Blood Pressure Measurements

The body height and weight were measured using a portable SECA 206 portable body meter (Seca, Hamburg, Germany) and Tanita digital lithium weighing scale (Tanita, Tokyo, Japan). Then, the body mass index (BMI) was computed by using the formula "body weight (kg)/height (m)^2". The waist, hip and calf circumferences were measured using Lufkin tape, and the readings were taken to the nearest 0.1 cm. Body composition (fat mass, fat-free mass, skeletal muscle mass and body fat percentage) was analyzed using a Bioelectrical Impedance Analysis Inbody S10 (Biospace, Seoul, Korea). The systolic and diastolic blood pressure was measured twice consecutively using an automatic digital blood pressure monitor (OMRON, Kyoto, Japan) to get the average reading.

Assessment of Dietary Intake

Participants' usual food and drinks intake in a week were recorded using a validated Dietary Habits Questionnaire specialized for older adults.[7] Then, the dietary record of each participant was analyzed by using the Nutritionist Pro^{TM} Software to obtain their respective nutrient intake profile.

Blood Sample Collection and Biochemical Analysis

Participants were instructed to fast overnight before blood sample collection. The fasting venous blood was then collected from the participants by a trained phlebotomist and was sent to accredited medical laboratories for biochemical analysis. The parameters included in the analysis are fasting blood glucose, hemoglobin, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride and albumin levels.

Physical Fitness Assessment

The participants' physical fitness was assessed using the Senior Fitness Test.[7] The Senior Fitness Test is a battery of tests, including a 2-minute step test, chair stand test, chair sit-and-reach test, timed up-and-go test, dominant hand-grip strength test and back scratch test. These fitness tests were used to measure aerobic endurance, lower limb muscle strength, lower body flexibility, mobility and balance, upper limb muscle strength and upper body flexibility.

Cognitive Function Assessment

The Malay version of Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) were used to evaluate global function. Despite their similarity in cognitive function evaluation, the MoCA test is of greater sensitivity to detect mild cognitive impairment with less ceiling effect than MMSE.[8] Meanwhile, the Digit Symbol Test and Digit Span Test, the subsets of the Wechsler Adult Intelligence Scale, were used to evaluate the information processing, visual-motor speed, visual memory and coordination and attention, concentration and memory, respectively. Then, the Rey Auditory Verbal Learning Test (RAVLT) was used to determine short-term verbal memory and verbal learning. The cognitive function assessment was described in detail by Shahar et al.[7]

Psychosocial and Functional Status Assessment

Activities of Daily Living (ADL), Instrumental Activity of Daily Living (IADL) and World Health Organization Disability Assessment Schedule 2.0 (WHODAS 2.0) were used to assess the functioning in self-care, independent living skills and disability, respectively. Meanwhile, the Medical Outcome Social Support (MOSS) survey was used to measure functional social support. Personality disorder and depressive symptoms were determined by using Eysenck Personality Questionnaire and Geriatric Depression Scale. The feelings of loneliness, perception of stress, self-perceived success, and life satisfaction were evaluated using the three-item Loneliness Scale, four-item Perceived Stress Scale, eight-item Flourishing Scale and Satisfaction with Life Scale, respectively. The psychosocial and functional status assessment was described in detail by Shahar et al.[7]

Audiometric Assessment

The audiometric assessment was carried out with slight modification from Mukari et al method.[9] Briefly, the hearing status of the participants was carried out by trained personnel in a sound-treated mobile booth using a calibrated Madsen Itera II diagnostic audiometer with TDH 39 headphones. The air-conduction thresholds for left and right ears were obtained monaurally at frequencies of 0.5, 1, 2, 3, 4, 6 and 8 kHz. In this study, we categorized the hearing thresholds in the better ear as pure-tone average (PTA) for the octave frequencies from 0.5 to 4 kHz and high-frequency pure-tone average (HFA) for the octave from 2 to 8kHz. The HL is defined as a threshold average greater than 25 dB hearing level.

Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences version 25.0 (IBM Corp, Armonk, New York, USA). The prevalence of HL is calculated by

dividing the number of participants with HL based on PTA (PTAHL) or HFA (HFAHL) by the total number of participants in this study. Next, the variables were compared between participants with normal hearing and HL of each PTA category by using independent *T*-test for continuous variables or Chi-square test for categorical variables. The variables that appeared to be significant ($p < 0.05$) in the univariate tests were further subjected to binary logistic regression analysis. Then, variables with significant ($p < 0.05$) associations with HL were included in the final multivariate binary logistic regression model and were adjusted with other well-known confounding factors (age, sex, ethnicity, years of education, smoking and alcohol drinking habits, multimorbidity and BMI). Variables that were found to be significant ($p<0.05$) in the final multivariate logistic regression model were identified as the potential risk factors of PTAHL or HFAHL.

Results

The characteristics of the participants included and excluded from the analysis are presented in Table 1. There are no significant differences in most of the characteristics, except for the proportion of ethnic ($p < 0.01$), with higher percentage of Malay population and lower Chinese and Indian populations among the excluded participants.

The hearing loss based on HFA among community-dwelling older adults was more prevalent (83%) than hearing loss based on the PTA criterion (75.5%). Table 2 shows the characteristics of the participants based on their hearing status. Compared to participants with normal hearing, participants with PTAHL were more likely ($p < 0.05$) to be men (47.6%), older (69.49 ± 6.07 years), Chinese (59.7%), have cardiovascular diseases (16.8%), higher waist circumference (91.24 ± 11.93 cm), higher body fat mass (25.21 ± 8.89 kg), lower intake of vitamin C (124.83 ± 69.11 mg/day), niacin (9.55 ± 3.50 mg/day), potassium (1355.39 ± 425.50 mg/day), zinc (3.30 ± 1.45 mg/day) and copper (0.61 ± 0.27 mg/day), higher fasting blood glucose level (6.44 ± 2.27 mmol/L), had lower chair sit-and-reach test (9.61 ± 12.39 cm), timed up and go test (10.44 ± 3.21 seconds) and back scratch test (19.05 ± 13.98 cm) scores, scored lower on the MMSE (23.47 ± 4.94), MoCA (19.39 ± 6.12), Digit Symbol Test (5.91 ± 3.05), Digit Span Test (7.67 ± 2.68) and RAVLT T5 score (37.97 ± 11.41), had higher WHODAS 2.0 (3.90 ± 6.30) and flourishing scale (14.89 ± 7.26) scores.

Meanwhile, the participants with HFAHL were more likely to be men (48.1%), older (69.30 ± 5.99 years), have cardiovascular diseases (15.7%), higher waist circumference (90.94 ± 11.91 cm), higher intake of carbohydrate (220.31 ± 62.05 g/day), lower intake of vitamin C (126.29 ± 69.42 mg/day), potassium (1376.04 ± 453.15 mg/day), magnesium (135.51 ± 54.32 mg/day), zinc (3.36 ± 1.46 mg/day) and copper (0.62 ± 0.31 mg/day), higher fasting blood glucose level (6.38 ± 2.20 mmol/L), lower HDL level (1.40 ± 0.35 mmol/L), had lower chair sit-and-reach test (9.43 ± 12.22 cm), timed up and go test (10.29 ± 3.15 seconds) and back scratch test (18.92 ± 13.99 cm) scores, scored lower in MMSE (23.65 ± 4.86), MoCA (19.63 ± 6.04), Digit Symbol Test (6.06 ± 3.06), Digit Span Test (7.71 ± 2.68) and RAVLT T5 score (38.15 ± 11.33) and scored higher in WHODAS 2.0 (3.60 ± 6.11).

The variables that are significantly associated with the PTAHL and HFAHL as analyzed using the binary logistic regression are listed in Table 3. These variables were then entered into the final multiple logistic regression model to determine the risk factors associated with both types of HL (Table 4). Following multifactorial adjustments, being older (OR: 1.239; 95% CI: 1.062–1.445), having higher waist circumference (OR: 1.158; 95% CI: 1.015–1.322), lower intake of niacin (OR: 0.909; 95% CI: 0.831–0.988) and potassium (OR: 0.998; 95% CI: 0.996–1.000), and scored lower in RAVLT T5 (OR: 0.905; 95% CI: 0.838–0.978) were identified as the risk factors of PTAHL. In the meantime, increasing age (OR: 1.117; 95% CI: 1.003–1.244), higher intake of carbohydrate (OR: 1.018; 95% CI: 1.006–1.030), lower intake of potassium (OR: 0.998; 95% CI: 0.997–0.999), and scored lower in RAVLT T5 (OR: 0.922; 95% CI: 0.874–0.973) were associated with increased risk of having HFAHL. Being older, lower intake of potassium and lower RAVLT T5 score appeared to be the common risk factors for PTAHL and HFAHL.

Discussion

We found that the prevalence of PTAHL among Malaysian older adults aged 60 years and above was 75.5%. This prevalence is within the range of 69.9–76.2%, as reported in previous studies.[6,10,11] However, the National Health Morbidity Survey (NHMS) 2018 showed that the prevalence of self-reported hearing disability in older Malaysians aged 60 years and above was only 6.4%.[12] The marked differences in the prevalence rate between our current findings and the NHMS 2018 could be attributed to different approaches to detect hearing impairment.

Table 1 The Characteristics of the Included and Excluded Participants in the Study

Characteristic	n (%) or Mean ± SD			
	Total Eligible Participants 573 (100)	Included Participants 253 (44.2)	Excluded Participants 320 (55.8)	p-value
Age	68.30 ± 6.07	68.59 ± 5.92	68.08 ± 6.19	0.318
Sex				
Male	243 (42.4)	109 (43.1)	134 (41.9)	0.771
Female	330 (57.6)	144 (56.9)	186 (58.1)	
Ethnicity				
Malay	181 (31.6)	57 (22.5)	124 (38.8)	0.001**
Chinese	291 (50.8)	144 (56.9)	147 (45.9)	
Indian	96 (16.8)	50 (19.8)	46 (14.4)	
Others	5 (0.9)	2 (0.8)	3 (0.9)	
Smoking				
Yes	47 (8.2)	21 (8.3)	26 (8.1)	0.939
No	526 (91.8)	232 (91.7)	294 (91.9)	
Drinking alcohol				
Yes	47 (8.2)	27 (10.7)	20 (6.3)	0.055
No	526 (91.8)	226 (89.3)	300 (93.8)	
Education (years)	6.86 ± 4.70	6.55 ± 4.66	7.11 ± 4.72	0.156
Medical history				
Hypertension	328 (57.2)	140 (55.3)	188 (58.8)	0.412
Hypercholesterolemia	240 (41.9)	110 (43.5)	130 (40.6)	0.492
Cardiovascular disease	67 (11.7)	34 (13.4)	33 (10.3)	0.248
Diabetes mellitus	180 (31.4)	82 (32.4)	98 (30.6)	0.647
Physical measurement				
BMI (kg/m^2)	25.70 ± 4.36	25.31 ± 4.23	26.01 ± 4.44	0.057
Waist circumference (cm)	90.43 ± 11.74	90.05 ± 11.96	90.73 ± 11.56	0.491
Hip circumference (cm)	99.59 ± 9.17	99.03 ± 8.98	100.03 ± 9.32	0.195
Calf circumference (cm)	34.78 ± 3.70	34.67 ± 3.37	34.86 ± 3.95	0.541
Systolic (mmHg)	137.12 ± 19.32	135.88 ± 19.01	138.11 ± 19.54	0.180
Diastolic (mmHg)	76.54 ± 12.57	76.52 ±12.44	76.55 ± 12.70	0.977

Note: **p<0.01.
Abbreviation: BMI, body mass index.

This present study used pure tone audiometry to assess the hearing status of participants, which is the gold standard test for hearing acuity.[2] Meanwhile, the NHMS 2018 used the self-reporting Washington Group of Disability questionnaires to evaluate hearing disability among older adults.[12] Hence, variations may occur since the outcome measurements of these two assessments are of two different perspectives. Although the use of the self-reported hearing questionnaire is of notable advantages over the PTA assessment in terms of cost and ease of administration, biases may occur due to the inter-individual variability of perception and belief on hearing impairments, resulting in underestimation or overestimation of HL.[13,14] The accuracy of self-reported HL is also

Table 2 The Characteristics of the Participants Aged 60 Years and Above, Overall and by Hearing Status

Characteristic	n (%) or Mean ± SD						
	Total (253; 100)	Normal-PTA 62 (24.5)	PTAHL 191 (75.5)	p-value	Normal-HFA 43 (17.0)	HFAHL 210 (83.0)	p-value
Age	68.59 ± 5.92	65.81 ± 4.44	69.49 ± 6.07	<0.001***	65.14 ± 4.20	69.30 ± 5.99	<0.001***
Sex							
Male	109 (43.1)	18 (29.0)	91 (47.6)	0.010*	8 (18.6)	101 (48.1)	<0.001***
Female	144 (56.9)	44 (71.0)	100 (52.4)		35 (81.4)	109 (51.9)	
Ethnicity							
Malay	57 (22.5)	22 (35.5)	35 (18.3)	0.039*	12 (27.9)	45 (21.4)	0.705
Chinese	144 (56.9)	30 (48.4)	114 (59.7)		24 (55.8)	120 (57.1)	
Indian	50 (19.8)	10 (16.1)	40 (20.9)		7 (16.3)	43 (20.5)	
Others	2 (0.8)	0 (0.0)	2 (1.0)		0 (0.0)	2 (1.0)	
Smoking							
Yes	21 (8.3)	3 (4.8)	18 (9.4)	0.256	2 (4.7)	19 (9.0)	0.341
No	232 (91.7)	59 (95.2)	173 (90.6)		41 (95.3)	191 (91)	
Drinking alcohol							
Yes	27 (10.7)	7 (11.3)	20 (10.5)	0.856	6 (14.0)	21 (10.0)	0.444
No	226 (89.3)	55 (88.7)	171 (89.5)		37 (86.0)	189 (90.0)	
Education (years)	6.55 ± 4.66	7.50 ± 4.92	6.24 ± 4.55	0.063	7.12 ± 5.09	6.43 ± 4.57	0.379
Medical history							
Hypertension	140 (55.3)	29 (46.8)	111 (58.1)	0.119	19 (44.2)	121 (57.6)	0.106
Hypercholesterolemia	110 (43.5)	27 (43.5)	83 (43.5)	0.990	17 (39.5)	93 (44.3)	0.567
Cardiovascular disease	34 (13.4)	2 (3.2)	32 (16.8)	0.007**	1 (2.3)	33 (15.7)	0.019*
Diabetes mellitus	82 (32.4)	15 (24.2)	67 (35.1)	0.112	11 (25.6)	71 (33.8)	0.294
Tinnitus	43 (17.0)	7 (11.3)	36 (18.8)	0.169	3 (7.0)	40 (19.0)	0.055
Physical measurement							
BMI (kg/m^2)	25.31 ± 4.23	24.29 ± 3.96	25.58 ± 4.29	0.078	24.93 ± 4.06	25.39 ± 4.27	0.516
Waist circumference (cm)	90.05 ± 11.96	86.38 ± 11.38	91.24 ± 11.93	0.005**	85.72 ± 11.40	90.94 ± 11.91	0.009**
Hip circumference (cm)	99.03 ± 8.98	97.88 ± 8.75	99.40 ± 9.04	0.248	99.00 ± 9.24	99.04 ± 8.95	0.981
Calf circumference (cm)	34.67 ± 3.37	34.58 ± 3.39	34.70 ± 3.38	0.801	34.91 ± 3.44	34.62 ± 3.37	0.606
Fat mass (kg)	24.57 ± 8.80	22.61 ± 8.28	25.21 ± 8.89	0.045*	23.24 ± 7.80	24.84 ± 8.98	0.283

Fat free mass (kg)	39.09 ± 8.25	38.67 ± 8.76	39.15 ± 8.10	0.692	37.37 ± 8.53	39.37 ± 8.17	0.152
Skeletal muscle mass (kg)	20.84 ± 4.94	20.64 ± 5.27	20.91 ± 4.84	0.710	19.85 ± 5.14	21.05 ± 4.89	0.151
Percentage body fat (%)	38.09 ± 9.72	36.45 ± 9.56	38.62 ± 9.74	0.130	38.03 ± 9.12	38.10 ± 9.86	0.969
Systolic (mmHg)	135.88 ± 19.01	135.44 ± 17.13	136.02 ± 19.63	0.840	135.23 ± 16.77	136.00 ± 19.46	0.813
Diastolic (mmHg)	76.52 ±12.44	77.78 ± 11.06	76.12 ± 12.85	0.373	78.70 ± 11.75	76.09 ± 12.55	0.226
Nutrition							
Energy (kcal/day)	1605.80 ± 389.46	1571.75 ± 388.59	1616.95 ± 390.24	0.452	1527.38 ± 384.64	1623.08 ± 389.42	0.155
Protein (g/day)	67.45 ± 19.74	69.27 ± 21.48	66.85 ± 19.17	0.426	69.23 ± 22.21	67.06 ± 19.20	0.525
Carbohydrate (g/day)	215.21 ± 61.91	202.04 ± 56.61	219.53 ± 63.10	0.066	192.09 ± 56.36	220.31 ± 62.05	0.008**
Fat (g/day)	52.94 ± 18.64	54.04 ± 20.00	52.58 ± 18.22	0.611	53.53 ± 20.69	52.81 ± 18.22	0.822
Vitamin A (μg/day)	1004.94 ± 531.24	1076.15 ± 520.49	980.85 ± 534.11	0.245	1082.16 ± 518.85	987.22 ± 533.78	0.301
Vitamin C (mg/day)	135.01 ± 80.21	166.13 ± 101.82	124.83 ± 69.11	0.006**	174.57 ± 110.02	126.29 ± 69.42	0.010*
Vitamin D (mg/day)	0.44 ± 1.01	0.47 ± 1.03	0.43 ± 1.01	0.800	0.26 ± 0.80	0.48 ± 1.05	0.212
Vitamin E (mg/day)	5.39 ± 3.05	6.19 ± 4.23	5.12 ± 2.51	0.078	5.83 ± 2.78	5.29 ± 3.10	0.304
α-tocopherol (mg/day)	0.24 ± 0.87	0.38 ± 1.59	0.19 ± 0.42	0.400	0.44 ± 1.85	0.19 ± 0.41	0.393
Thiamin (mg/day)	2.35 ± 4.27	2.20 ± 4.84	2.40 ± 4.08	0.760	2.14 ± 4.74	2.40 ± 4.17	0.727
Riboflavin (mg/day)	1.35 ± 0.51	1.39 ± 0.46	1.33 ± 0.53	0.447	1.40 ± 0.49	1.34 ± 0.52	0.487
Niacin (mg/day)	9.83 ± 3.58	10.70 ± 3.71	9.55 ± 3.50	0.037*	10.23 ± 3.46	9.75 ± 3.46	0.433
Pyridoxine (mg/day)	0.73 ± 0.37	0.79 ± 0.34	0.71 ± 0.38	0.208	0.81 ± 0.35	0.71 ± 0.38	0.140
Folate (μg/day)	119.11 ± 71.76	130.44 ± 75.11	115.41 ± 70.46	0.174	117.75 ± 61.08	119.42 ± 74.05	0.893
Cobalamin (μg/day)	3.50 ± 3.79	3.70 ± 3.36	3.44 ± 3.93	0.649	4.42 ± 4.78	3.30 ± 3.52	0.087
Pantothenic Acid (mg/day)	0.30 ± 0.47	0.32 ± 0.51	0.30 ± 0.45	0.794	0.34 ± 0.57	0.30 ± 0.44	0.629
Vitamin K (μg/day)	38.28 ± 118.30	60.00 ± 181.0	31.16 ± 88.30	0.255	74.53 ± 207.70	30.29 ± 86.11	0.188
Sodium (mg/day)	1320.30 ± 682.60	1245.24 ± 786.47	1344.87 ± 645.64	0.344	1213.35 ± 832.28	1343.87 ± 645.24	0.269
Potassium (mg/day)	1443.28 ± 512.31	1711.65 ± 649.26	1355.39 ± 425.50	<0.001***	1748.31 ± 645.59	1376.04 ± 453.15	0.001**
Calcium (mg/day)	520.14 ± 233.19	579.47 ± 283.23	500.71 ± 211.66	0.059	548.92 ± 239.29	513.79 ± 232.00	0.384
Iron (mg/day)	13.81 ± 5.13	13.67 ± 5.33	13.85 ± 5.08	0.819	13.46 ± 5.59	13.88 ± 5.04	0.634
Phosphorus (mg/day)	994.66 ± 360.82	1056.36 ± 408.70	974.45 ± 342.59	0.141	1024.06 ± 385.82	988.17 ± 355.84	0.565
Magnesium (mg/day)	141.42 ± 60.72	154.95 ± 75.23	136.99 ± 54.69	0.103	168.18 ± 79.30	135.51 ± 54.32	0.015*
Zinc (mg/day)	3.48 ± 1.62	4.02 ± 1.97	3.30 ± 1.45	0.014*	4.03 ± 2.13	3.36 ± 1.46	0.016*
Selenium (μg/day)	25.10 ± 18.97	25.71 ± 21.33	24.90 ± 18.20	0.784	26.06 ± 22.86	24.89 ± 18.07	0.722
Copper (mg/day)	0.65 ± 0.35	0.79 ± 0.51	0.61 ± 0.27	0.012*	0.81 ± 0.47	0.62 ± 0.31	0.015*
Manganese (mg/day)	0.27 ± 0.36	0.33 ± 0.41	0.24 ± 0.33	0.110	0.33 ± 0.43	0.25 ± 0.34	0.226
Molybdenum (μg/day)	0.17 ± 1.04	0.25 ± 1.12	0.15 ± 1.01	0.515	0.30 ± 1.30	0.14 ± 0.97	0.399
Biochemical							
Haemoglobin (g/L)	15.23 ± 3.30	14.59 ± 3.14	15.47 ± 3.33	0.126	14.96 ± 3.48	15.29 ± 3.26	0.617
Fasting blood glucose (mmol/L)	6.27 ± 2.06	5.76 ± 1.11	6.44 ± 2.27	0.007**	5.72 ± 1.06	6.38 ± 2.20	0.011*

(*Continued*)

https://doi.org/10.2147/CIA.S340432 DovePress

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Table 2 (Continued).

Characteristic	n (%) or Mean ± SD						
	Total (253; 100)	Normal-PTA 62 (24.5)	PTAHL 191 (75.5)	p-value	Normal-HFA 43 (17.0)	HFAHL 210 (83.0)	p-value
Cholesterol (mmol/L)	4.99 ± 1.06	4.99 ±1.03	5.00 ± 1.07	0.990	4.93 ± 0.97	5.01 ± 1.08	0.720
HDL (mmol/L)	1.43 ± 0.37	1.51 ± 0.39	1.40 ± 0.36	0.060	1.55 ± 0.40	1.40 ± 0.35	0.028*
LDL (mmol/L)	2.90 ± 0.98	2.88 ± 0.97	2.91 ± 0.99	0.877	2.82 ± 0.89	2.92 ± 1.00	0.574
Triglyceride (mmol/L)	1.45 ± 0.78	1.31 ± 0.77	1.50 ± 0.78	0.145	1.23 ± 0.70	1.49 ± 0.79	0.076
Albumin (g/L)	42.15 ± 2.64	42.15 ± 2.08	42.15 ± 2.80	0.998	42.27 ± 2.07	42.12 ± 2.74	0.763
Physical fitness							
2-minute step test (number)	64.69 ± 29.26	69.03 ± 23.70	63.29 ± 30.77	0.133	69.33 ± 27.51	63.73 ± 29.58	0.260
Chair stand test (number)	10.57 ± 3.26	11.05 ± 3.17	10.42 ± 3.29	0.194	10.97 ± 2.99	10.49 ± 3.32	0.380
Chair sit-and-reach (cm)	8.61 ± 12.06	5.47 ± 10.46	9.61 ± 12.39	0.020*	4.60 ± 10.48	9.43 ± 12.22	0.018*
Timed up and go (seconds)	10.08 ± 3.08	8.95 ± 2.30	10.44 ± 3.21	<0.001***	9.04 ± 2.50	10.29 ± 3.15	0.016*
Dominant hand grip strength (kg)	24.07 ± 7.53	23.67 ± 6.73	24.20 ± 7.78	0.638	23.34 ± 6.75	24.22 ± 7.69	0.462
Back scratch (cm)	17.40 ± 14.22	12.25 ± 13.84	19.05 ± 13.98	0.001**	9.96 ± 13.10	18.92 ± 13.99	<0.001***
Cognitive function							
MMSE	24.10 ± 4.71	26.07 ± 3.19	23.47 ± 4.94	<0.001***	26.33 ± 3.01	23.65 ± 4.86	<0.001***
MoCA	20.04 ± 6.04	22.07 ± 5.33	19.39 ± 6.12	0.002**	22.10 ± 5.64	19.63 ± 6.04	0.015*
Digit symbol	6.31 ± 3.215	7.60 ± 3.42	5.91 ± 3.05	0.001**	7.59 ± 3.68	6.06 ± 3.06	0.019*
Digit span	7.87 ± 2.73	8.48 ± 2.84	7.67 ± 2.68	0.045*	8.67 ± 2.87	7.71 ± 2.68	0.037*
RAVLT T5 score	39.66 ± 11.59	44.86 ± 10.65	37.97 ± 11.41	<0.001***	46.88 ± 10.15	38.15 ± 11.33	<0.001***
Psychosocial and functional status							
ADL	6.00 ± 0.00	6.00 ± 0.00	6.00 ± 0.00	-	6.00 ± 0.00	6.00 ± 0.00	-
IADL	13.19 ± 1.17	13.37 ± 1.27	13.13 ± 1.83	0.327	13.48 ± 1.02	13.13 ± 1.82	0.091
WHODAS 2.0	3.32 ± 5.79	1.44 ± 3.00	3.90 ± 6.30	<0.001***	1.90 ± 3.46	3.60 ± 6.11	0.016*
Satisfaction with Life Scale	8.32 ± 2.54	8.72 ± 2.22	8.19 ± 2.62	0.129	8.70 ± 2.23	8.24 ± 2.56	0.299
Eysenck Personality Questionnaire	1.17 ± 1.99	0.92 ± 1.89	1.25 ± 2.03	0.257	0.88 ± 1.96	1.23 ± 2.00	0.304
Loneliness Scale	3.28 ± 0.99	3.22 ± 0.94	3.30 ± 1.01	0.597	3.33 ± 1.13	3.28 ± 0.97	0.739
Flourishing Scale	14.22 ± 7.01	12.10 ± 5.72	14.89 ± 7.26	0.003**	12.98 ± 6.57	14.46 ± 7.09	0.220
Perceived Stress Scale	4.12 ± 2.95	3.75 ± 2.79	4.24 ± 3.00	0.261	3.80 ± 2.80	4.19 ± 2.98	0.451
MOSS Survey	40.09 ± 13.45	42.48 ± 13.94	39.35 ± 13.24	0.121	41.40 ± 15.17	39.83 ± 13.11	0.502
Geriatric Depression Scale	3.07 ± 2.57	2.54 ± 2.07	3.24 ± 2.70	0.065	2.48 ± 2.10	3.19 ± 2.64	0.101

Notes: Data are presented as mean ± SD or n (%). *p<0.05; **p<0.01; ***p<0.001.

Abbreviations: ADL, activities of daily living; BMI, body mass index; HDL, high-density lipoprotein; IADL, instrumental activities of daily living; LDL, low-density lipoprotein; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; MOSS, Medical Outcome Social Support; RAVLT, Rey Auditory Verbal Learning Test; WHODAS 2.0, World Health Organization Disability Assessment Schedule 2.0.

Table 3 The Univariate Scores for Individual Risk Factors of PTAHL and HFAHL

Risk Factors Category	Item	PTAHL			HFAHL		
		p-value	Exp(B)	[95% CI]	p-value	Exp(B)	[95% CI]
Sociodemographic	**Age**	<0.001***	1.135	1.068–1.206	<0.001***	1.166	1.081–1.258
	Sex (Male)						
	- Female	Reference	Reference	Reference	Reference	Reference	Reference
	- Male	0.011*	2.224	1.200–4.125	0.001**	4.054	1.796–9.153
	Ethnicity						
	- Malay	Reference	Reference	Reference	-	-	-
	- Chinese	0.011*	2.389	1.225–4.658	-	-	-
	- Indian	0.039*	2.514	1.049–6.028	-	-	-
	- Others	0.999	-	-	-	-	-
Medical history	**Cardiovascular diseases**						
	- No	Reference	Reference	Reference	Reference	Reference	Reference
	- Yes	0.016*	6.038	1.403–25.975	0.046*	7.831	1.041–58.892
Physical measurement	**Waist circumference**	0.006**	1.036	1.010–1.063	0.010*	1.039	1.009–1.070
	Fat mass	0.047*	1.036	1.001–1.073	-	-	-
Nutrition	**Carbohydrate**	-	-	-	0.009**	1.009	1.002–1.015
	Vitamin C	0.001**	0.994	0.990–0.998	0.001**	0.993	0.990–0.997
	Niacin	0.040*	0.917	0.845–0.996	-	-	-
	Potassium	<0.001***	0.999	0.998–0.999	<0.001***	0.999	0.998–0.999
	Magnesium	-	-	-	0.004**	0.992	0.987–0.997
	Zinc	0.006**	0.773	0.642–0.930	0.021*	0.797	0.657–0.966
	Copper	0.002**	0.252	0.105–0.603	0.004**	0.267	0.108–0.657
Biochemical	**Fasting blood glucose**	0.056	1.288	0.994–1.670	0.103	1.302	0.948–1.786
	HDL	-	-	-	0.031*	0.338	0.126–0.905
Physical fitness	**Chair sit-and-reach**	0.022*	1.032	1.005–1.060	0.020*	1.039	1.006–1.073
	Timed up and go	0.001**	1.261	1.097–1.450	0.016*	1.207	1.036–1.407
	Back scratch	0.002**	1.038	1.014–1.062	<0.001***	1.054	1.024–1.085
Cognitive function	**MMSE**	<0.001***	0.846	0.772–0.926	0.001**	0.829	0.741–0.927
	MoCA	0.003**	0.920	0.871–0.972	0.017*	0.926	0.869–0.986
	Digit symbol	0.001**	0.853	0.777–0.935	0.008**	0.869	0.784–0.964
	Digit span	0.047*	0.898	0.807–0.998	0.039*	0.882	0.782–0.994
	RAVLT T5 score	<0.001***	0.949	0.923–0.975	<0.001***	0.935	0.905–0.965
Psychosocial status	**WHODAS 2.0**	0.009**	1.126	1.030–1.231	0.099	1.073	0.987–1.167
	Flourishing Scale	0.010*	1.083	1.019–1.151	-	-	-

Notes: *p<0.05; **p<0.01; ***p<0.001.

Abbreviations: HDL, high-density lipoprotein; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; RAVLT, Rey Auditory Verbal Learning Test; WHODAS 2.0, World Health Organization Disability Assessment Schedule 2.0.

subjected to various factors such as the degree of HL, demographic, socioeconomic and psychological factors.[15] Besides, the prevalence of HFAHL (83.0%) is slightly higher than PTAHL (75.5%). Such observation is possible since ARHL, particularly the sensory presbycusis subtype, predominantly develops at higher frequency region first before deterioration to the lower frequency regions of the cochlea.[16]

Our current findings showed that increasing age is a common risk factor for both PTAHL and HFAHL. The association between age and HL is well documented. It is predicted that starting from the second decade of life, the prevalence of HL will double for every ten years increase in age.[1] Moreover, the prevalence of HL with a moderate or higher level of severity increases dramatically from 15.4% among those aged between 60 and 69 years old to

Table 4 The Risk Factors Associated with PTAHL and HFAHL Among the Community-Dwelling Older Adults

Risk Factors Category	Item	PTAHL			HFAHL		
		p-value	Exp(B)	[95% CI]	p-value	Exp(B)	[95% CI]
Sociodemographic	**Age**	0.006**	1.239	1.062–1.445	0.043*	1.117	1.003–1.244
Physical measurement	**Waist circumference**	0.029*	1.158	1.015–1.322	-	-	-
Nutrition	**Carbohydrate**	-	-	-	0.003**	1.018	1.006–1.030
	Niacin	0.043*	0.909	0.831–0.988	-	-	-
	Potassium	0.028*	0.998	0.996–1.000	<0.001***	0.998	0.997–0.999
Cognitive function	**RAVLT T5 score**	0.012*	0.905	0.838–0.978	0.003**	0.922	0.874–0.973

Notes: *p<0.05; **p<0.01; ***p<0.001.
Abbreviation: RAVLT, Rey Auditory Verbal Learning Test.

58.2% among those over 90 years worldwide.[2] The progression of HL with increasing age is mainly due to cochlear and neural degeneration that affects auditory processing and sound interpretation.[17] Furthermore, the accumulated insults to the ear due to the constant exposure to various risk factors of HL may increase across the life span, contributing to higher risk of having HL as people live longer.

Our study demonstrated that higher waist circumference is associated with an increased risk of HL among older adults. There is evidence suggesting that waist circumference, a measurement of abdominal obesity and central adiposity is more prominent in predicting HL compared to BMI, which reflects the overall adiposity of the body.[18,19] The effect of BMI on hearing levels is inconclusive. Adults with obesity were reported to be at a higher risk of having hearing impairments than their counterparts with normal BMI.[20] This might be because of excessive adiposity can lead to obesity-induced oxidative stress, which may cause damage to the auditory structures of the inner ear.[21] Besides, obesity and other associated comorbidities such as hypertension, cardiovascular diseases and diabetes mellitus can cause changes to the blood vessels and capillaries that supply the ear, disrupting the blood circulation in the inner ear and subsequently damaging the hair cells.[20] In contrast, Kim et al found that underweight individuals are more likely to develop HL than those with normal BMI.[22] These rather contradictory findings may be due to the deposition of fat around the abdominal has a stronger association with other obese-related comorbidities, which may contribute to the development and progression of HL as compared to overall adiposity.[23]

In this present study, we demonstrated that a higher carbohydrate intake is associated with an increased risk of having HL. Previously, Gopinath et al reported that high intake of glycemic load diet and total carbohydrate among older adults was associated with an increased risk of developing HL.[24] Similarly, Rosenhall et al reported that high consumption of low molecular weight carbohydrates was correlated to poorer hearing thresholds at high frequencies.[25] Besides, people with high consumption of carbohydrates, especially those simple carbohydrates and added sugars, are more likely to become obese and develop other comorbidities like cardiovascular diseases, dyslipidemia and diabetes mellitus.[26] As discussed previously, obesity and comorbidities like cardiovascular diseases may affect the hearing by disrupting the blood flow in the inner ear.[20]

Contrary to our current findings, Spankovich et al demonstrated that a higher intake of carbohydrates confers protective effects against HL among older adults.[27] This is possible since complex carbohydrates such as cereal fiber, whole grain and vegetables are food with low glycemic index and may lead to increased satiety and lower energy intake.[28] Previously, high consumption of food rich in complex carbohydrates and dietary fiber is associated with smaller waist circumference and reduced adiposity.[29] Hence, different sources of carbohydrates may have discrete biological effects on the body and affect the hearing capacity differently.

Niacin, or better known as vitamin B3, is a precursor of the two biologically active coenzymes, namely the nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP).[30] Apart from its well-known physiological function in energy production, cellular signaling, DNA repair, and the central nervous system, the role of niacin in auditory function remains unclear. To date, there are only a few studies reporting

the association of niacin intake with HL. Our findings showed that inadequate intake of niacin might increase the risk of having ARHL. Previously, Kang et al reported that niacin intake is correlated to better hearing acuity in only the univariate linear regression model, while Kim and Chung demonstrated that higher consumption of niacin reduced the risk of developing ARHL in older adults.[31,32] However, a recent study conducted by Choi et al showed that niacin intake was not associated with the development of ARHL.[33] The possible mechanism underlying the protective effects of niacin against HL is that niacin can prevent the degeneration of the spiral ganglion neurons and preserve the synaptic contacts between the spiral ganglion neurons and hair cells via the activation of NAD^+-SIRT3 pathway following intense exposure to noise, as demonstrated in vivo.[34] Hence, further study is needed to confirm the role of niacin in the prevention of ARHL.

In agreement with our current findings, Jung et al demonstrated that higher potassium intake is associated with better hearing levels and lower prevalence of HL in adults.[35] Potassium is one of the essential nutrients that help maintain fluids and electrolytes balance, the transmission of nerve impulse and muscle contraction in our body.[36] A high potassium ion concentration is found in the cochlear endolymph and is required to generate endocochlear potential (EP) that drives the sensory transduction in the hair cells.[37] During sound transduction, the vibration of the basilar membrane causes the opening of the specialized transduction channel on the stereocilia of hair cells. The potassium ions are driven into hair cells due to the presence of EP, hence exciting the hair cells. Disruption in potassium homeostasis in the endolymph due to degeneration of stria vascularis (a specialized ion transport structure in cochlear), reduced expression of specific potassium ion channels, and mutation in genes encoding the potassium-regulating proteins in the cochlear has been associated with sensorineural HL.[38,39]

However, despite playing an essential physiological role in sound transduction, the direct association between potassium intake and HL remains unclear. Previously, consumption of a high-potassium diet was demonstrated to increase the aldosterone level in the body and subsequently leads to the increased expression of Na^+/K^+ ATPase and NKCC1 in the stria vascularis, suggesting that higher intake of potassium could help in the maintenance of EP in the endolymph and protect against ARHL.[40–43] Furthermore, a high potassium diet may also protect against HL indirectly via its beneficial effects on hypertension and glycemic control.[36]

Current findings also demonstrated that older adults with HL had lower scores in the RAVLT cognitive test. The RAVLT is a neuropsychological tool widely used to assess functions such as attention, memory, and learning ability in the auditory-verbal domain.[44] Although hearing impairment is widely accepted as one of the causes of cognitive impairment among older adults, this association may be directional because HL and cognitive impairment share the same common risk factors and pathogenesis mechanisms, such as cardiovascular diseases, microcirculation disorders, oxidative stress and inflammation.[45,46] However, the auditory-verbal memory of participants with hearing impairment should be analyzed carefully to avoid any misleading interpretation. It is suggested that the participants' hearing capacity may affect the RAVLT test outcomes since the administration of RAVLT requires communication between the assessor and participant and the test items are presented verbally to the participants.[47] Cognitively intact adults with HL performed significantly worse than their normal-hearing counterparts in auditory-verbal memory tests, thus underestimating the actual cognitive performance of the participants diagnosed with HL.[48]

In the present study, participants with HL generally had lower performance in other cognitive tests as well. However, only RAVLT T5 scores appeared to be associated with HL in the final multiple logistic regression model. Hence, instead of being recognized as cognitive impaired, we cannot rule out the possibility of lower performance in the RAVLT test among the participants with HL was due to their inability to listen correctly to the commands and test items presented verbally by the assessor. Furthermore, a recent study conducted by Füllgrabe (2020) demonstrated that despite with perfect audibility of the test items, the cognitive test performance of the participants was compromised in the simulated-HL condition.[49] This is possibly due to the additional cognitive resources required for auditory perceptual processing following simulated-HL condition, limiting the remaining cognitive resources for the execution of other cognitive processes.[46] Future studies involving a prospective cohort population are needed to verify the relationship between the RAVLT scores and HL.

As there is no cure for HL, the hearing aid is one of the options to reduce the detrimental effects of HL. However,

in Malaysia, the rate of hearing aid adoption was only 2.7% among older adults with HL.[50] Thus, the determination of modifiable risk factors of HL as presented in the present study may help audiologists or policymakers in designing a more comprehensive and effective hearing health awareness or HL prevention program.

Conclusion

In conclusion, increasing age, having higher waist circumference, lower intake of niacin and potassium, higher intake of carbohydrates and lower RAVLT T5 score were associated with increased risk of ARHL. Identifying these risk factors may help develop preventive and management strategies for ARHL in older adults. Nevertheless, this study has demonstrated its strength in using objective measures to assess HL and its association using a wide range of health factors. However, due to the cross-sectional nature of this study, which makes the causal link between the risk factors and ARHL inconclusive, a future longitudinal-cohort study is needed.

Abbreviations

ADL, Activities of Daily Living; ARHL, age-related hearing loss; BMI, body mass index; EP, endocochlear potential; HDL, high-density lipoprotein; HFA, high-frequency pure-tone average; HFAHL, hearing loss based on high-frequency pure-tone average; HL, hearing loss; IADL, Instrumental Activity of Daily Living; LDL, low-density lipoprotein; LRGS-TUA, Long-term Research Grant Scheme - Towards Useful Ageing; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; MOSS, Medical Outcome Social Support; NAD, nicotinamide adenine dinucleotide; NADP, nicotinamide adenine dinucleotide phosphate; NHMS, National Health Morbidity Survey; PTA, pure-tone average; PTAHL, hearing loss based on pure-tone average; RAVLT, Rey Auditory Verbal Learning Test; WHODAS 2.0, World Health Organization Disability Assessment Schedule 2.0; YLDs, years lived with disability.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments

The authors thank the participants and the team members of the study for their participation and support given.

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.

Funding

This work was supported by the Ministry of Higher Education Malaysia under the Long-term Research Grant Scheme (LRGS/1/2019/UM-UKM/1/4 and LRGS/BU/2012/UKM-UKM/K/01).

Disclosure

The authors report no conflicts of interest in this work.

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