Global Cognitive Function is Associated with Sex, Educational Level, Occupation Type, and the Speech Recognition Rate in Older Chinese Adults: A Single-Center, Prospective, Cross- Sectional Study

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Abstract

Background: The development of cognitive impairment may be delayed if its risk factors are identified, it can be detected, its developmental trend can be predicted, and early intervention can be performed. This study primarily aimed to investigate the association between global cognitive function and hearing loss, educational level, and occupation type, and to determine any differences in such associations according to sex among older Chinese adults.

Methods: In this cross-sectional study, we prospectively recruited individuals in one ear, nose, and throat outpatient clinic who were above 55 years of age and could write independently, with no diagnosis of severe vision impairment. Audiometric examinations included otoscopy, acoustic immittance, pure-tone audiometry, and speech audiometry for each ear. Cognitive function was evaluated by using the Chinese version of the Mini-Mental State Examination (MMSE). Univariable linear regression analyses were conducted to assess the relationship between each variable and MMSE score. Multivariable linear regression analyses were performed to evaluate the relationship between variables and MMSE scores after adjusting for independent variables that were statistically significant in the univariable analyses.

Results: We enrolled 219 individuals, including 98 men (mean ± standard deviation age, 63.08±6.64 years) and 121 women (62.64±7.17 years). The overall MMSE scores of the normal hearing and mild, moderate, and severe-to-profound hearing loss groups were 24.53±3.10, 24.36±3.92, 23.32±3.88, and 20.92±6.53, respectively. MMSE scores were higher among participants with higher educational levels ($p<0.001$) and were significantly correlated with occupation type ($p<0.001$). MMSE scores were significantly higher in men than in women ($p<0.001$). However, upon analysis of the five subdomains, significant differences were only observed for attention and calculation ($p<0.001$) and language ($p=0.011$). We further explored whether educational level is related to the cognitive differences between the sexes by comparing the distribution of educational levels between men and women, with the chi-square test; there was no significant difference in educational level between the sexes ($p=0.070$).

Conclusions: We discovered statistically significant relationships between global cognitive function and sex, educational level, and occupation type. Sex-specific strategies may be required to improve healthcare policies.

Background

It is well-known that cognitive impairment (CI) affects the quality of life, social functioning, and well-being of older adults.As the number of older adults is rising with the average life expectancy,this is becoming a severe social and public health problem. The prevalence of mild cognitive impairment(MCI) reported in population-based epidemiological studies ranges from 3% to 19% in adults older than 65 years [1]. MCI can act as a transitional stagein the development of dementia with a range of conversion of 10%-15% per year, although it does not interfere substantially with individuals' daily activities[2]. Worldwide, approximately 50 million people live with dementia, and this number is projected to increase to 152 million by 2050, rising particularly in low- and middle-income countries where around two-thirds of people with dementia live[3].

In addition to the development of pharmacological preventions and treatments for CI, modifiable risk factors need to be examined and addressed. Many studies have been conducted in the attempt to identify the risk factors for cognitive decline [4], with many[5,6] pointing toward age-related hearing loss (ARHL) as an independent risk factor.Depending on its severity, ARHLseems to play a significant role in cognitive decline. However, recentquantitative studies of the relationship between hearing loss (HL) and cognitive function weremainly based on self-reported measures[7–9], rather than on a combination of subjective measures and objective audiometry.

Having a higher educational leveland/or a complex occupational roleare generally considered to be protective against cognitive decline[10,11]and to contribute to cognitive reserve.Other putative protective factors may themselves also be caused by a higher educational level and occupational complexity[12].It should also be noted that, in one study[13],a higher educational level decreased the risk of dementia, whereas occupational complexity was not associated with dementia.Furthermore, a couple of studies[13,14]revealed that the cut-off point at which educational level is protective against dementia may vary depending on the age composition of the cohort in question. Therefore, the influence of education and occupation type on cognitive performance in older adultsis unclear.

In China, the prevalence of CI was 62.7% in women and 45.4% in men over 75 years of age in one study [15], althoughthere are differences in hypotheses and results between studies regarding factors related to cognitive decline between the sexes among older individuals. The results of certain studies [16,17]seem to provide an explanation for the bettercognitive performanceof men than women:the effects of endogenous estrogen decline at older age.Older women are more likely to develop dementia than men of the same age, probably in part because, on average, older women have had less education than older men[5].When adjusting for educational status, it seems that women typically have a better verbal memory than men,which is consistent with the hypothesis of cognitive reserve[18]. However, the difference incognitive performance between the sexesafter adjustment for age remains unknown.

The development of CI may be delayed ifits risk factors are identified, it can be detected,its developmental trend canbe predicted, and early interventioncan be performed.Therefore, the main aim of this study was to investigate the associations between global cognitive function (as defined by using Mini-Mental State Examination [MMSE] scores) andHL, educational level, and occupation type,and to explore whether there are any differences in such associations according to sex among older Chinese adults.

Methods

Study population

In this cross-sectional study, weprospectively recruited individuals in the ear, nose, and throat outpatient clinic of West China Hospital from June 2020 to February 2021. Individuals were included in this study if they were aged 55 years or older, could write independently, and had no diagnosis of severe vision impairment. Participants were excluded if they were living alone, had a history of more than 30 min of unconsciousness due to trauma, had first-degree relatives who had been diagnosed with dementia, or had hypertension (systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg)[19], diabetes mellitus (glycated hemoglobin >6.5%)[20], hemorrhaging, cerebral infarction, cerebrovascular disease diagnosed with magnetic resonance imaging, a body mass index >24 or <18.2 kg/m^2, thyroid dysfunction, abnormal electrocardiogram characteristics, chronic obstructive pulmonary disease (COPD Assessment Test score ≥11)[21], syphilis, or unilateral/bilateral conductive/mixed HL. This study was approved by the Biomedical Research Ethics Committee of West China Hospital (No.2020285). All participants voluntarily signed an informed consent form.

Information acquisition

This study was conducted via face-to-face interviews with highly trained researchers. Demographic information (including name, sex, date of birth, occupation type, educational level, etc.) and individual medical history (dementia, hypertension, hemorrhaging, cerebral infarction, cerebrovascular disease, etc.) were collected by using a pre-designed questionnaire which was analyzed per individual by researchers.

Audiometric examinations

A combination of otoscopy, acoustic immittance, pure-tone audiometry, and speech audiometry was conducted for each ear in a soundproof room with ambient noise <30 dBA (A-weighted sound pressure level). Bilateral pure-tone hearing thresholds at frequencies of 0.25, 0.5, 1, 2, 4, and 8 kHz were measured at 5-dB increments in decibels hearing level (dB HL). Pure-tone threshold average (PTA) of the better ear for four frequencies (0.5, 1, 2, and 4 kHz) were adopted to define participants' degree of hearing, according to guidelines published by the World Health Organization (1997)[22]. The cut-off values for mild, moderate, severe, and profound hearing loss were 25-, 40-, 60-, and 80-dB HL, respectively. The speech recognition rate was determined with speech audiometry. The acoustic immittance test consisted of tympanometry and the acoustic reflex decay test, and was used to measure the state of the middle ear and the function of the cochlear and facial nerves.

Cognitive assessment

Cognitive function was evaluated by using the Chinese version of theMMSE. The MMSE has a 30-point scale and is commonly usedto screen individuals for CI, with high sensitivity and specificity.It covers five cognitive domains: orientation, registration, attention and calculation, recall, and language. The diagnostic criteria for CI varied with the participant's educational level. CIwas defined as an MMSE score<17 in the illiterate group, <20 in the primary-school group, <23 in the junior/high-school, and <24 in the "above" group.

Statistical analysis

Continuous variables (age, duration of HL, PTA, and speech recognition rate) are described as means and standard deviations. Categorical variables (binary variable: sex; multi-categorical variables: educational level and occupation type) are presented as numbers with percentages. Student's t-test, one-way analysis of variance,the Mann-Whitney U test, and the Kruskal-Wallis test were used for comparison of continuous variables among groups, and the chi-squared test or Fisher's exact test was used for comparison of categorical variables among groups, as appropriate. Univariable linear regression analyses were conducted to assess the relationship between each variable and the MMSE score. Multivariable linear regression analyses were performed to evaluate the relationship between variables and the MMSE score after adjusting for independent variables that were statistically significant in the univariable analyses.

All statistical analyses were performed with IBM SPSS Statistics for Windows, version 25.0(IBM Corp., Armonk, NY, USA) and GraphPad Prism 9.0 software (GraphPad Software, Inc., San Diego, CA, USA), and a two-sided P-value $\leq$0.05 was considered statistically significant.

Results

Demographic characteristics

After strict observance of the inclusion and exclusion criterion, a total of 219 individuals were enrolled in this study, including 98 men (44.7%; mean age, 63.08±6.64 years) and 121 women (55.3%; mean age, 62.64±7.17 years). With regard to HL, 64(29.2%) participants had normal hearing, 70(32.0%) had mild HL, 73(33.3%) had moderate HL, and 12(5.5%) had severe-profound HL (severe and profound HL groups were combined because of the small sample size). Participant age, duration of HL, PTA, and the speech recognition rate differedamong the four groups. Individuals with worse hearing were typically older, had had HL for a longer time, had a higher PTA, and had a worse speech recognitionrate than those with better hearing. However, there were no differences in sex, educational level, or occupation type among the groups. The specific sociodemographic and hearing characteristics of the participants are summarized in Table 1.

Table 1. Socio-demographic characteristics of all participants by hearing loss degree

Characteristics	Hearing-loss degree				P Value
	Normal (n=64)	Mild (n=70)	Moderate (n=73)	Severe-profound (n=12)	
Age, mean (SD), years	59.92(4.62)	63.23(6.83)	64.42(7.51)	66.42(9.22)	**0.001**
Sex, n (%)					
Male	23(23.47)	33(33.67)	37(37.75)	5(5.10)	0.146
Female	41(33.88)	37(30.58)	36(29.75)	7(5.79)	
Education, n (%)					
Illiteracy	2(16.67)	3(25.00)	5(41.67)	2(16.67)	
Primary school	6(23.08)	9(34.62)	11(42.31)	0(0.00)	0.249
Junior/ high school	36(29.51)	36(29.51)	42(34.43)	8(6.56)	
Undergraduate/ master/ PhD	20(33.90)	22(37.29)	15(25.42)	2(3.39)	
Occupation type					
None	18(29.03)	18(29.03)	20(32.26)	6(9.68)	0.668
Retired	35(32.71)	33(30.84)	36(33.64)	3(2.80)	
Physical labor	6(24.00)	9(36.00)	8(32.00)	2(8.00)	
Mental labor	5(20.00)	10(40.00)	9(36.00)	1(4.00)	
Duration of HL, mean (SD), years	0.33(1.37)	1.87(4.47)	5.91(11.23)	13.21(15.15)	**0.000**
PTA, mean (SD), dB HL	15.94(4.71)	31.18(5.40)	49.38(5.78)	66.87(10.92)	**0.000**
Speech recognition rate, mean (SD), %	98.56(2.61)	94.57(10.64)	49.38(5.78)	66.88(10.92)	**0.000**

SD, standard deviation; dB HL, decibel hearing level; PTA, pure-tone thresholds average

Association between cognition and hearing

The overall MMSE scores of the normal hearing andmild, moderate, and severe-profound HL groups were 24.53±3.10, 24.36±3.92, 23.32±3.88, and 20.92±6.53, respectively. There was no significant association between MMSE score and the degree of HL (p=0.09). Linear regression analysis revealed that the MMSE score was negatively correlated tothe PTA (R^2=0.07, p<0.001, Figure 1) and positively related to the speech recognition rate (R^2=0.09, p<0.001, Figure 2).

Association between cognition and educational level

MMSE scores were higher among participants with higher educational levels (p<0.001). The overall MMSE scores of the illiterate, primary-school, junior/high-school, and undergraduate/master's/PhD groups were 16.67±3.87, 20.35±3.46, 24.16±3.23, and 26.31±2.49, respectively. The above trend among the four education levels was also present in the MMSE subdomains of orientation (p<0.001), attention and calculation (p<0.001), recall (p<0.001), and language (p<0.001),but not in that of registration (p=0.142, Figure 3).

Association between cognition and occupation

MMSE scores were significantly correlated with occupation type (p<0.001). The overall MMSE scores of the unemployed, retired, physical labor, and mental labor groups were 22.00±4.53, 24.94±2.84, 26.28±2.64, and 21.52±4.52, respectively. The distribution of the overall MMSE score and those for different occupation types is illustrated in Figure 4.

Association between cognition and sex

MMSE scores were significantly higher in men than in women (p<0.001). However, uponanalysis of the five subdomains, significant differenceswere only observed for attention and calculation (p<0.001) and language (p=0.011). Scores did not differ between sexes in terms of orientation (p=0.091), registration (p=0.985), or recall (p=0.128) (Figure 5).We further exploredwhether educational level is related to the cognitive differences between the sexesby comparing the distribution of educational levels between men and women, with the chi-squared test.Thisanalysis revealed no significant difference in the educational levelbetween the sexes (p=0.070, Table 2).

Table 2. The distribution difference of educational level between males and females

Sex, n (%)	Education level				
	Illiteracy	Primary school	Junior/ high school	Undergraduate/ master/ PhD	P-value
Male	2(2.04)	9(9.18)	55(56.12)	32(32.65)	0.070
Female	10(8.26)	17(14.05)	67(55.37)	27(22.21)	

Association of MMSE score with measured characteristics

Table 3 summarizes the results of the linear regression analyses. In the univariable analysis, the MMSE score was significantly associated with sex, educational level, occupation type, duration of HL, PTA, and speech recognition rate (all p<0.05). In the multivariable analysis, the duration of HL (p=0.794) and PTA (p=0.212) were excluded from the model. MMSE scores of retired participants and those with a physical job did not differ from those of unemployed participants (p=0.872 and p=0.239, respectively).

Table 3. Association of MMSE score with measured characteristics in the simple and multiple linear regression analysis

Characteristics	Univariate analysis			Multivariate analysis		
	β	**95% CI**	**P Value**	**β**	**95% CI**	**P Value**
Age	-0.06	-0.14, -0.01	0.096	-0.027	-	0.612
Sex						
Male	Reference			-	-	-
Female	-1.82	-2.85, -0.79	**0.001**	-1.30	-2.11, -0.50	**0.002**
Education						
Illiteracy	Reference			-	-	-
Primary school	3.68	1.54, 5.82	**0.001**	2.79	0.73, 4.85	**0.008**
Junior/ high school	7.49	5.63, 9.35	**<0.001**	6.46	4.67, 8.23	**<0.001**
Undergraduate/ master/ PhD	9.638	7.69, 11.58	**<0.001**	8.13	6.24, 10.02	**<0.001**
Occupation type						
None	Reference					
Retired	2.94	1.82, 4.07	**<0.001**	0.01	-	0.872
Physical labor	4.28	2.60, 5.96	**<0.001**	0.07	-	0.239
Mental labor	-0.48	-2.16, 1.20	0.573	-1.92	-3.17, -0.66	**0.003**
Duration of hearing loss	-0.08	-0.14, 0.01	**0.02**	-0.01	-	0.794
PTA	-0.07	-0.10, 0.03	**<0.001**	-0.08	-	0.212
Speech recognition rate	0.07	0.04, 0.10	**<0.001**	0.05	0.03. 0.08	**<0.001**

β, regression coefficient; CI, confidence interval; PTA, pure-tone thresholds average.

Discussion

Our study aimed to investigate the relationship between HL, educational level, occupation type, and cognition function among older Chinese adults, and whether such associations differ according to sex. Upon univariate analysis, we identified six factors associated with CI: sex, educational level, occupation type, duration of HL, PTA, and the speech recognition rate. After adjusting for covariates, the MMSE score was lower among female participants, those with a lower educational level, those with mental labor occupations, and those with a higher speech recognition rate than among other groups.

Wehave demonstrated that severe HLis associated with an increased risk of developing CI,manifesting as a lower MMSE score. In one study[23],HL affected episodic memory and attentional functions rather than executive functions. In fact, there is a large consensus that ARHL is an independent and modifiable risk factor for cognitive decline[24,25]. It is widely accepted that auditory deprivation triggers a vicious circle in older people, involving social isolation and CI [26,27]. Excessive cognitive load dedicated to auditory perceptual processing in everyday life causes structural changes in the brain and neurodegeneration, which are detrimental to other cognitive processes[28,29]. We combined subjective measures and objective audiometry in this studyanddiscovered that anincreased severityof HL and a poorer speech recognition rate were associated witha lower total MMSE score. Fetoni et al. [30]compared patients with and those without cognitive dysfunctionby means of the MMSE and discovered a higher hearing threshold in those with cognitive dysfunction ($p=0.049$).

Our research also revealed a statistically significant correlation between educational level and cognitive function in four of the five MMSE subdomains (all except registration), even after adjustment for confounding factors. In the registration subdomain, participantsare scored on the repetition of three words (i.e., “tree,”“clock,” and “car”) on the first attemptafter the words were read out to them. When sufficient auditory stimuli were presented, all three words weretypically repeated correctly irrespective of theparticipant’s educational level. In a Brazilian community sample, education also did not have an important effect on memory registration[31]. However, overall MMSE scores are highly dependent on educational level[32–34]. In a study of community-dwelling older adults aged 60 years or older,a higher educational level was associated with better cognitive function[35]. A higher educational level may provide sufficient cognitive reserve to counteract the effects of mild hearing impairment[36].

Our results support previous findings [10]that occupation type was related to cognitive function and may influence cognitive health through physiological and psychological pathways.Job stress may be a potential modifiable risk factor for adverse cognitive outcomes. In anepidemiological catchment area study in Baltimore [37],low-strain jobs were associated with statistically significantly lower decreases in cognitive scores than other job groups over an approximately eleven-year period.Normally, stress responses help individuals deal with urgent situations by activating the hypothalamus-pituitary-adrenal axis and increasing cortisol levels[38]. As a sense of low control is associated with high psychological stress, people with low job control bear higher risks of cognitive decline when facing high job demands[39]. Furthermore, a longer education, higher cognitive level of a person’s occupation (such as white collar jobs, e.g., clerical work, medical practice, and other occupations requiring a university degree), and greater engagement in cognitive leisure activities were reportedly related to higher MMSE scores[40]. Theseresultssupportthe view that cognitive stimulation throughout the course of a person’s life may contribute to cognitive reserve, thereby protecting that person against cognitive decline[41–43].

Across our cohorts, men generally performed better than womenforthe MMSEsubdomain of attention and calculation (but not the other subdomains)after adjustmentfor educational level. This result complements that of a report by the Lancet Commission[5]. However, only a few studies[44,45] have demonstrated the presence of sex differences in MCI. Better attention and calculation performance in men than in women could arise from the effect of estrogen[46] or sex-specific cognitive reserve[5].An 8-year longitudinal study revealed that cognitive deterioration in women with MCI was twice as fast as that in their male counterparts[47]. Even with the same degrees of hippocampal atrophy and the same rates of glucose metabolism in the temporal lobe, verbal memory performance reportedly differs between male and female patients with MCI [48]. The brain atrophy rate of female patients with MCI is reportedly higher than that of male patients, with an additional decrease of 1.0%–1.5% per year[49]. A possible explanation is that men may have higher resilience to MCI-related pathological damage to the brain [44] and better executive function than that exhibited bywomen, which is supported by the cognitive reserve theory.

The main strength of our study wasin the strictness ofthe inclusion and exclusion criteria, which may have reduced potential confounders.Another major strength was our ability to adjust for educational level to allow the comparison of sex differences among older adults, as educational level ishighly correlated with MCI.However, there were also several limitations to our study. First, our results were based on cross-sectional data rather than longitudinal trajectories of HL and cognitive function. Second, it was only a single-center study and, therefore,has limited reproducibility for older individuals. Third, we assessed cognitive function mainly with the MMSE.Future research should be focused on a more comprehensive approach forthe assessment of cognition, and longitudinal studies are neededto better explore the possible causal relationships between HL and cognitive function.

Conclusions

In the present study, we discovered statistically significant relationships between global cognitive function, as defined via the MMSE score, andsex, educational level, occupation type, and the speech recognition rate. Sex-specific strategies may be required to improve healthcare policies. These results indicate that the speech recognition ratemay be associated with cognitive impairment among older Chinese individuals, who should be screened routinely forthe early identification ofthe risk of cognitive decline. Our results need to be confirmed with prospective, longitudinal cohort studies.

Abbreviations

ARHL: age-related hearing loss

CI: cognitive impairment

dB HL: decibels hearing level

HL: hearing loss

MCI: mild cognitive impairment

MMSE: Mini-Mental State Examination

PTA: pure-tone thresholds average

Declarations

Ethics Approval and Consent to Participate

This study was approved by the Biomedical Research Ethics Committee of West China Hospital (No. 2020285). All participants voluntarily signed an informed consent form for participation in this study.

Consent for Publication

Not applicable.

Availability of Data and Materials

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

Competing Interests

The authors declare that they have no competing interests.

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Authors’ Contributions

HG: Concept, design, literature search, and manuscript editing. XY: Data analysis, statistical analysis, and manuscript editing. CD, ML, WK, and HL: Data acquisition. YZ: Supervision. ZM: Manuscript review. All authors read and approved the final manuscript.

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Figures

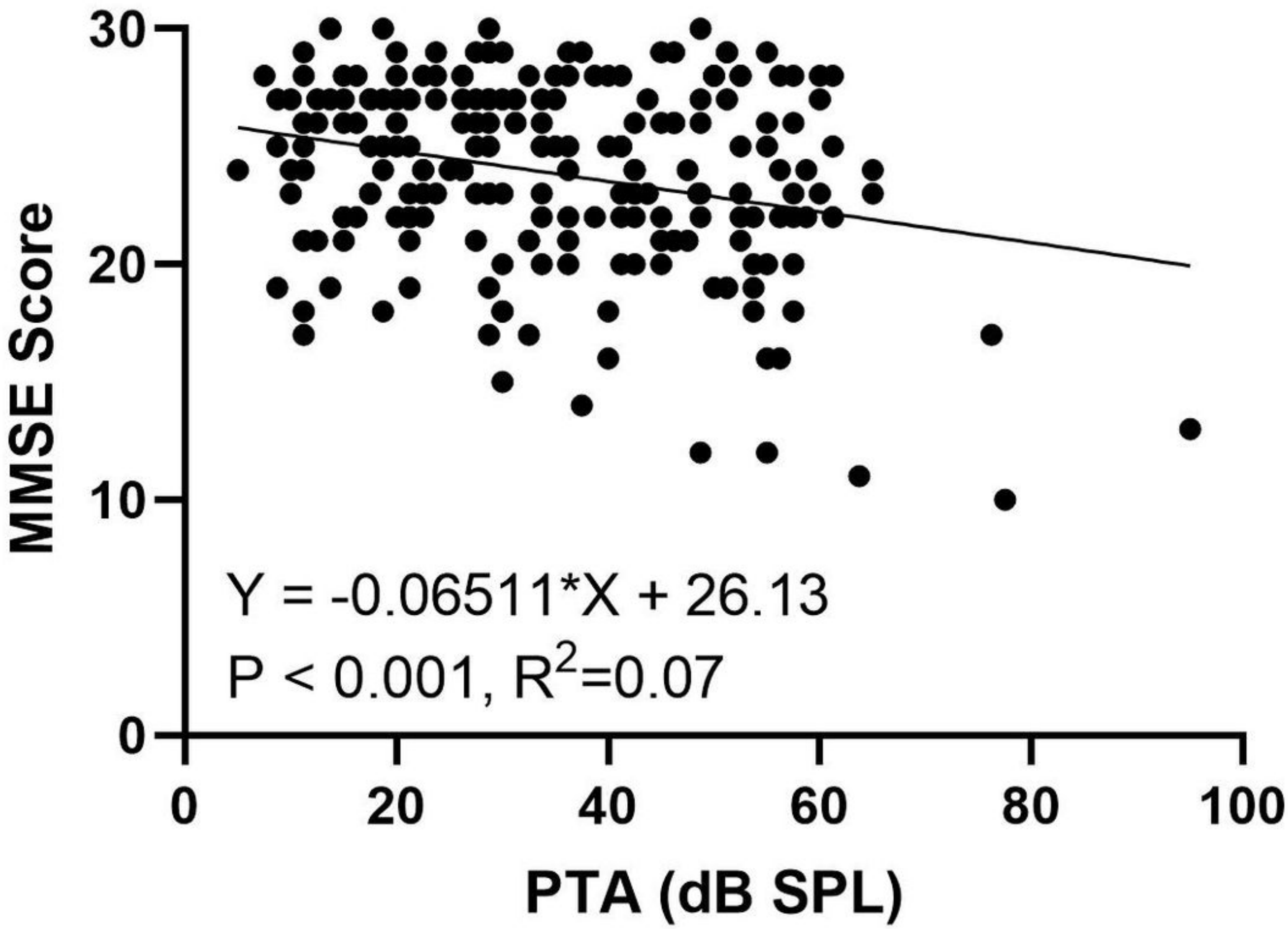

Figure 1

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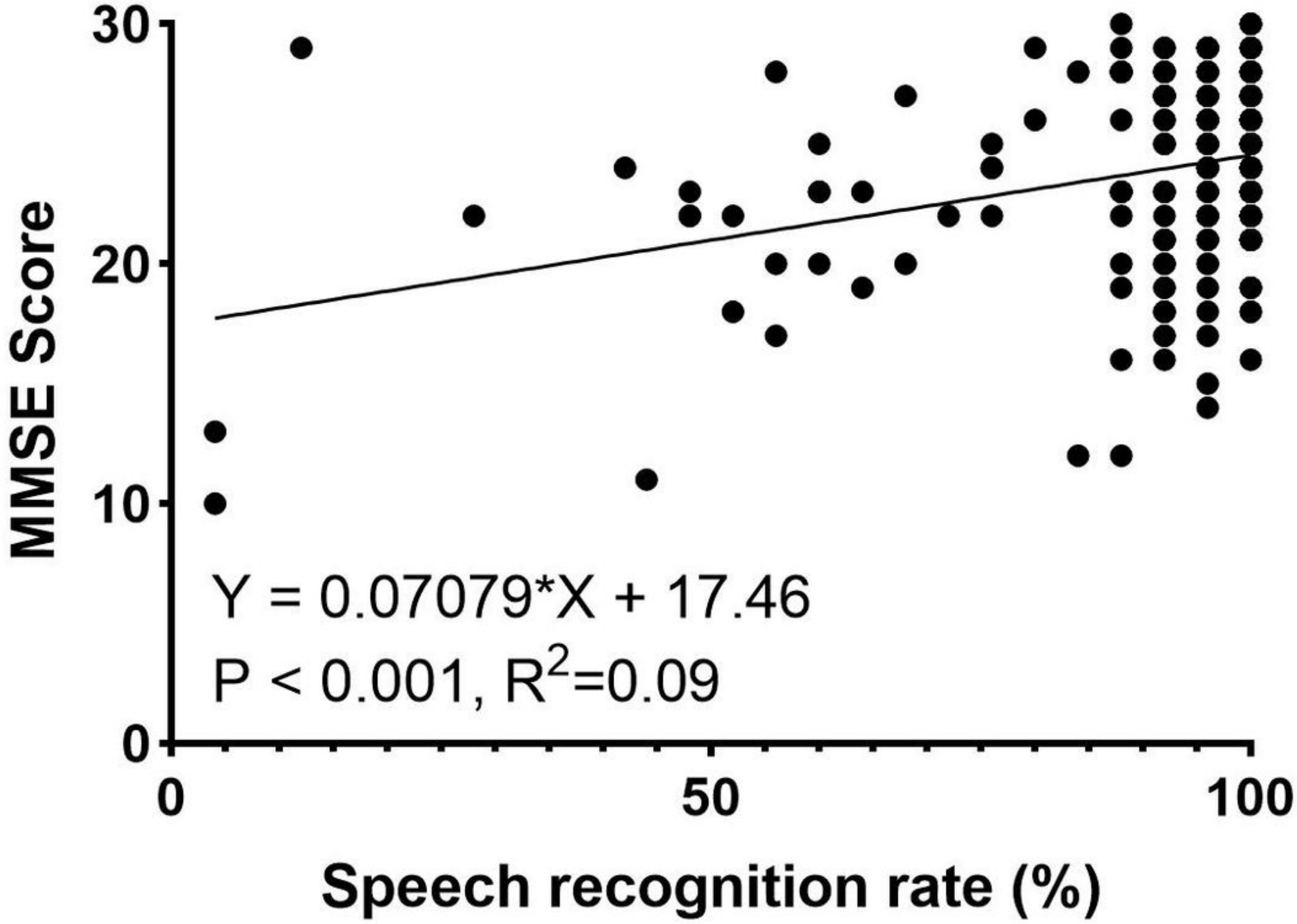

Figure 2

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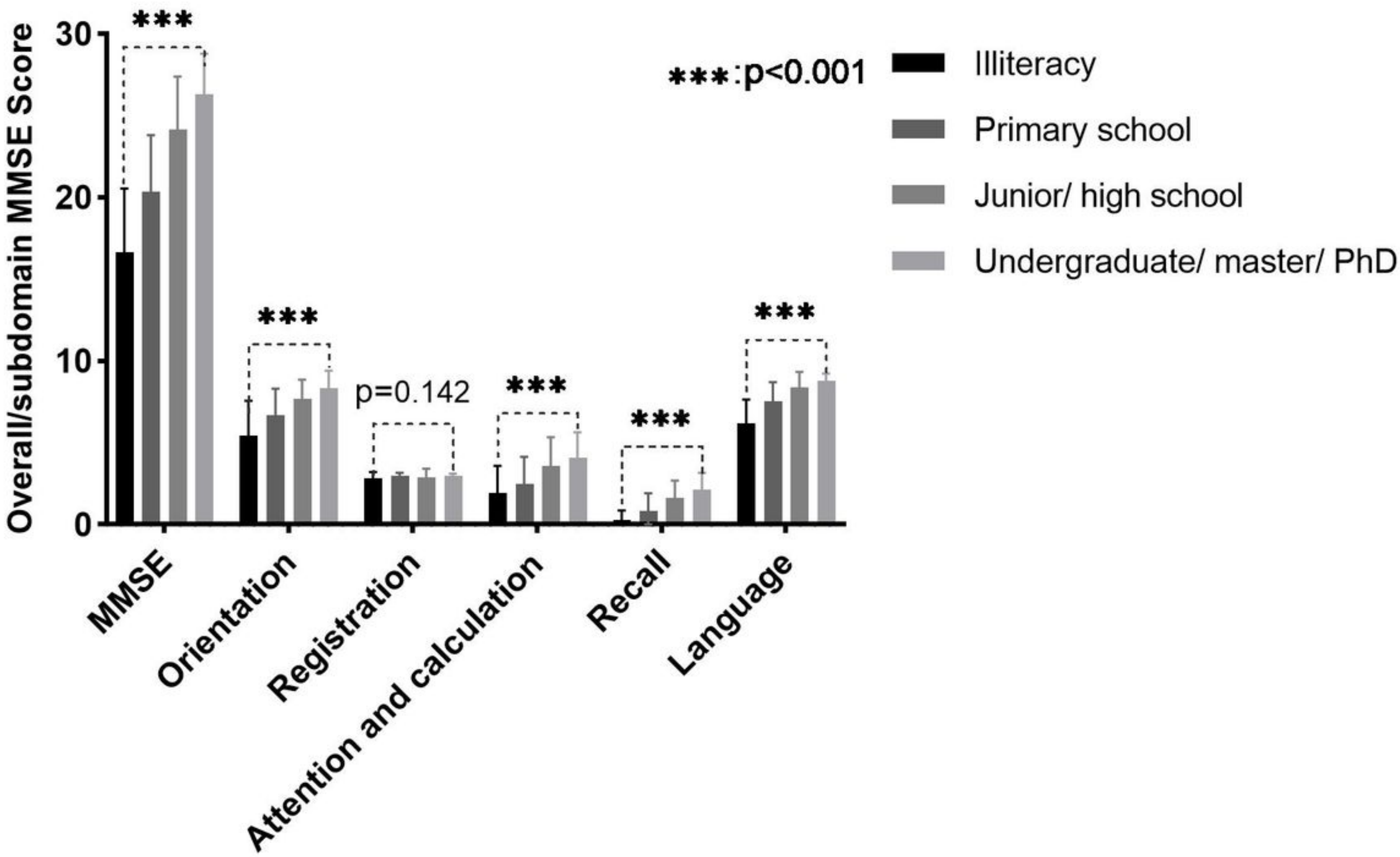

Figure 3

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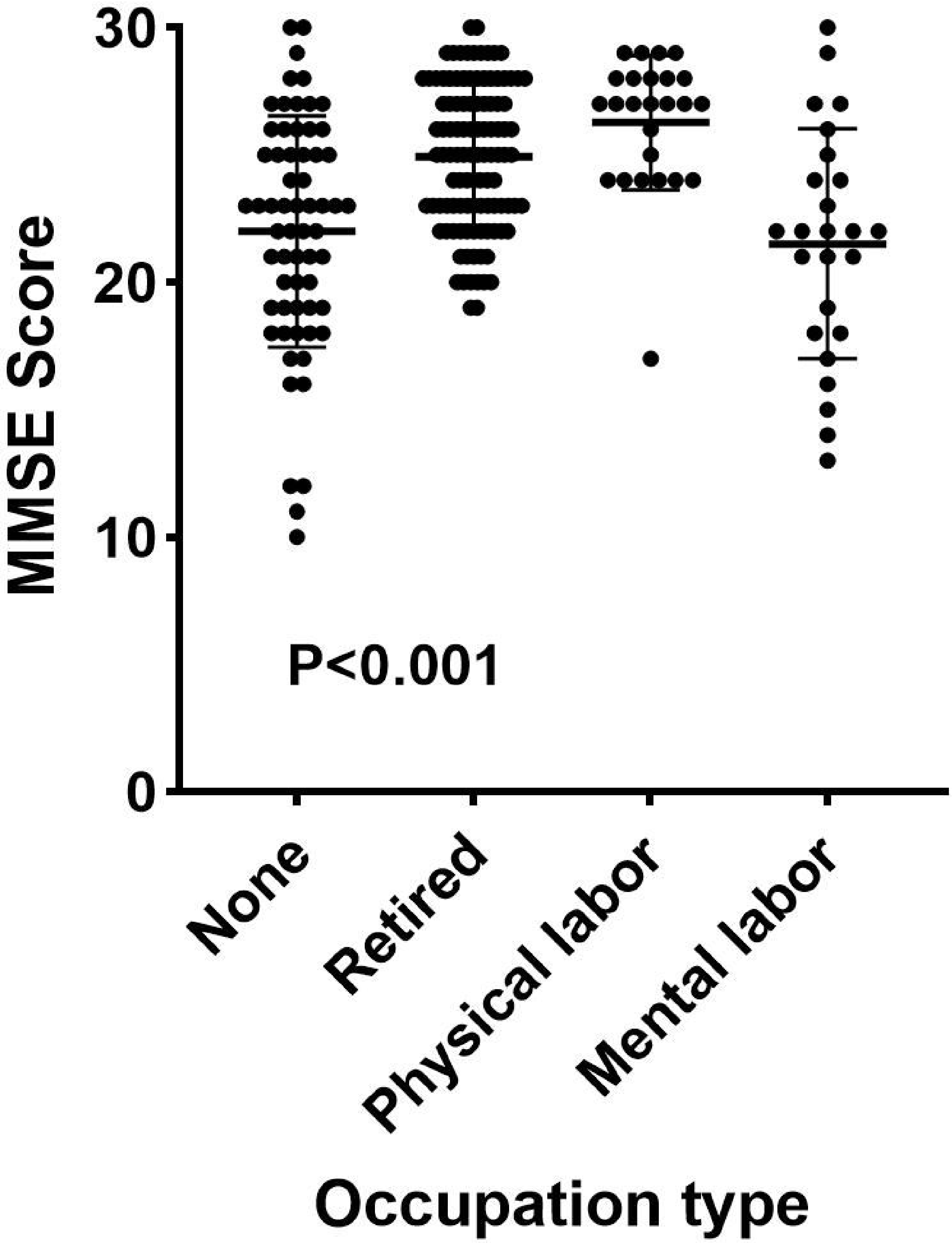

Figure 4

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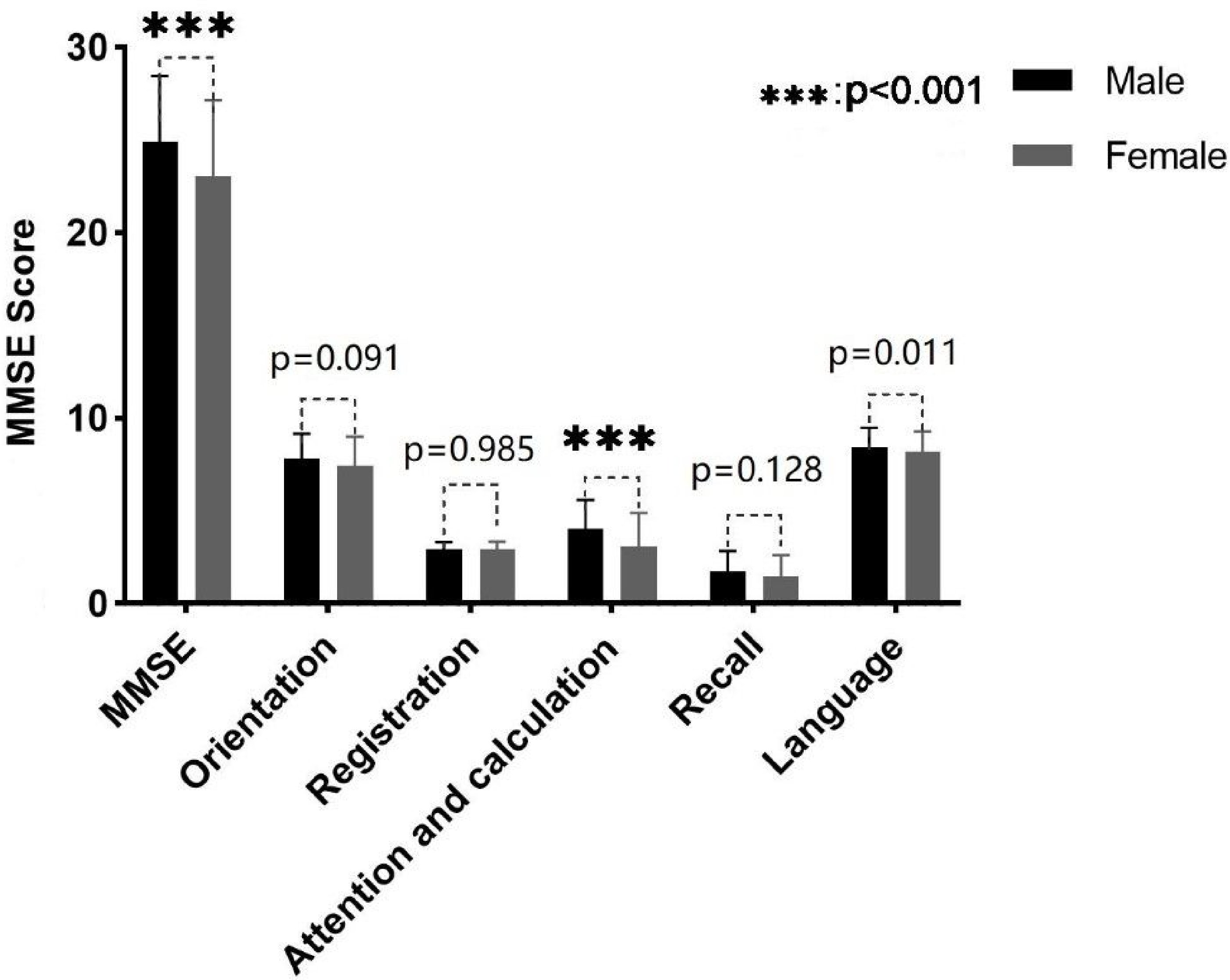

Figure 5

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