ISSN 2096-7071 (Print)
ISSN 2096-3101 (Online)
CN 10-1629/R1

CHINA CDC WEEKLY

Vol. 6 No. 32 Aug. 9, 2024

CCDC weekly

中国疾病预防控制中心周报

NATIONAL FITNESS DAY ISSUE

Preplanned Studies

CHINESE CENTER FOR DISEASE CONTROL AND PREVENTION
中国疾病预防控制中心
ISSN 2096-7071
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Preplanned Studies

Epidemiological Characteristics of Fracture Among Children Aged 6–17 Years — China, 2019–2021

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Summary

What is already known about this topic?

Fractures are a common and serious injury among children. While many studies have utilized clinical data, there is a lack of large-scale community-based research in China.

What is added by this report?

This cross-sectional study provides national and regionally representative data on the prevalence of fractures among Chinese children aged 6–17 years (6.93%), with higher rates observed in males than in females (8.13% *vs.* 5.71%) and in rural areas compared to urban areas (7.22% *vs.* 6.62%). The most common site of fracture was the upper limbs (4.24%, accounting for 63.0% of fractures).

What are the implications for public health practice?

The need to enhance awareness of fracture prevention is critical, particularly for children in rural areas and males in middle childhood. We recommend that local authorities increase investments in educational programs and child safety oversight. Additionally, promoting balanced diets for children, training in proper exercise techniques, and reinforcing participation in outdoor sports are essential.

Fractures are a prevalent injury among children, with one-third experiencing at least one fracture before reaching adulthood (*1*). This may be attributed to rapid bone growth, active bone mineral deposition, or their generally active lifestyles (*2*). Fractures not only cause intense physical pain but can also lead to serious complications, including infections, joint stiffness, functional limitations, and even disability. Such outcomes can severely hinder a child's physical development and quality of life, placing significant burdens on families and society. In response, the Chinese government has incorporated bone health initiatives into broader policies such as Healthy China 2030 (*3*). To effectively prevent fractures in children, it is crucial to understand their epidemiological patterns. Thus, this study explores the prevalence and common sites of fractures among children and adolescents aged 6–17 years in China.

This study utilizes survey data from the National Nutrition and Health Systematic Survey for Children aged 0–17 in China (2019–2021). It employed a multi-stage stratified random cluster sampling approach to conduct a cross-sectional survey across 28 urban and rural locations in 14 provincial-level administrative divisions (PLADs) spread over seven Chinese regions: East, North, Central, South, Southwest, Northwest, and Northeast China. In each survey site, data were collected from 12 age groups (6 to 17 years old), totaling 196 individuals per age group. Overall, 65,856 participants were initially recruited. Following the exclusion of respondents with missing data across various questionnaires, the final sample comprised 60,930 individuals. The methods for study design and sampling have been detailed previously (*4*). Informed consent was obtained from the guardians of all participants. The study received ethical approval from the Ethical Review Committee of the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention (No. 2019-009).

Questionnaires were employed to gather data from participants, including basic demographic details (gender, age, and residential address) and fracture-related information. Participants were initially queried about any hospital-diagnosed fractures in their history. If the response was affirmative, additional information was requested concerning the age at and location of the most recent fracture. Parents assisted children aged 6–9 years in completing the questionnaire, while those aged 10–17 years filled it out independently. Age, a continuous variable, was reported as means with standard deviations (SD), and categorical variables, such as fractures, were reported as *n* (%). Fracture prevalence was calculated by dividing the number of fracture cases by the population size, and differences in indices were compared using the chi-square test. Compound annual growth rates (CAGR) for fractures were determined by the twelfth root (n=12) of the total growth rate percentage between ages 6 to 17 years. The Cochran-Armitage trend test was employed to assess trends in fracture prevalence across age groups. All statistical analyses were conducted using SAS (version 9.4, SAS Institute Inc., Cary, USA). A two-sided P<0.05 was considered statistically significant.

The average age of the subjects was 11.57±3.43 years. Table 1 outlines the participants' general characteristics and the fracture prevalence across various demographics. The survey indicated that out of 4,222 children aged 6–17 years, there was a fracture history, giving a prevalence rate of 6.93%, with a higher incidence in males (8.13%) compared to females (5.71%, P<0.001). Geographic variations were also noted, with rural areas showing a higher fracture prevalence of 7.22% compared to 6.62% in urban areas (P<0.001). Regionally, fracture rates varied significantly (P<0.001), peaking at 9.40% in North China and dropping to a low of 4.79% in South China.

The prevalence of fractures varies with age and gender, ranging from 3.18% in males aged 6 years to 13.38% in those aged 17 years, and from 2.86% in females aged 6 years to 8.07% in females aged 17 years (Figure 1). The smallest difference in fracture prevalence between genders was observed in the 9-year-old group (3.77% in males versus 3.55% in females, χ^2=0.105, P=0.746), while the largest difference was in the 17-year-old group (13.38% in males versus 8.07% in females, χ^2=35.134, P<0.001). The CAGR of fracture prevalence from ages 6 to 17 was 12.72% for males and 9.04% for females, with a significant overall growth trend observed in both genders (P<0.001).

Regarding different fracture sites, the prevalence rates for fractures in the upper limbs, lower limbs, trunk, and head were recorded at 4.24%, 2.16%, 0.26%, and 0.11%, respectively. The prevalence rates in males were higher than in females for upper limbs (5.21% *vs*. 3.26%, P<0.001), lower limbs (2.30% *vs*. 2.02%, P=0.018), and head (0.15% *vs*. 0.07%, P=0.006), but there was no significant difference in the prevalence of trunk fractures. There was a significant age-associated increase in prevalence for both upper and lower limb fractures (P<0.001). Geographically, the prevalence of fractures in the lower limbs and head was higher in rural areas compared to urban areas (2.31% *vs*. 2.00% and 0.15% *vs*. 0.07%, respectively, P<0.05). Additionally, there were regional differences in the prevalence rates of fractures in the upper limbs, lower limbs, and trunk across seven regions (P<0.001).

In a study of 4,222 children with a history of fractures, the majority involved the upper limbs, accounting for 65.9% of males and 58.9% of females (Figure 2). Fractures of the lower limbs were reported in 28.6% of males and 35.6% of females. Fractures involving the trunk and head were less common, comprising less than 5% of fractures in both genders. Similar distributions were observed across different gender and age subgroups, as detailed inSupplementary Figure S1 (available at https://weekly.chinacdc.cn/). The incidence of fractures in both the upper and lower limbs initially increased with age, peaking at around 10 years old at 7.1% for upper limbs in males and 6.89% in females, and at 3.12% for lower limbs in males and 4.29% in females, before subsequently declining.

DISCUSSION

This cross-sectional study provides nationally and regionally representative data on the prevalence of fractures among Chinese children and adolescents aged 6–17 years. The observed prevalence of fractures in this demographic was 6.93%, which is significantly higher than the rate in Chinese adults aged 25–34 years (2.05 per 1,000 people) (*5*). This indicates that children and adolescents constitute a high-risk group for fractures, presenting substantial public health challenges. Furthermore, the prevalence of fractures among children varies by ethnicity. Over recent decades, numerous studies have investigated the epidemiology of childhood fractures in various regions, including Scandinavia and the United Kingdom (UK). In our study, the fracture rate was lower compared to white children in the UK (14%, N=10,856) and comparable to non-white children (8.1%, N=1,711) aged 0–14 years from a population-based household survey in the UK (*6*). Moreover, the China national fracture study in 2014 (N=512,187) reported a fracture incidence of 3.21 per 1,000 people across all ages, also lower than that observed among white populations (*5*). The ethnic disparities in fracture prevalence among children could be attributed to genetic factors, differences in bone mineral densities, or dietary variations. Additionally, lower engagement in high-risk activities among Chinese children may explain some of the ethnic differences (*6*).

Childhood fractures exhibit significant variations by gender and age. Males consistently experience a higher

TABLE 1. Prevalence of fractures among children and adolescents aged 6–17 years — China, 2019–2021.

Characteristics	*N* (%)	All fracture sites		Upper limbs		Lower limbs		Trunk		Head	
		Prevalence [% (95% *CI*)]	*P*	Prevalence [% (95% *CI*)]	*P*	Prevalence [% (95% *CI*)]	*P*	Prevalence [% (95% *CI*)]	*P*	Prevalence [% (95% *CI*)]	*P*
Gender			<0.001		<0.001		0.018		0.271		0.006
Male	30,700 (50.4)	8.13 (7.82, 8.44)		5.21 (4.96, 5.46)		2.30 (2.13, 2.46)		0.28 (0.22, 0.34)		0.15 (0.10, 0.19)	
Female	30,230 (49.6)	5.71 (5.45, 5.97)		3.26 (3.06, 3.46)		2.02 (1.86, 2.18)		0.23 (0.18, 0.29)		0.07 (0.04, 0.10)	
Age group (years)			<0.001		<0.001		<0.001		0.599		0.716
6–8	15,590 (25.6)	3.52 (3.23, 3.80)		2.09 (1.87, 2.32)		0.99 (0.84, 1.15)		0.21 (0.14, 0.28)		0.09 (0.04, 0.14)	
9–11	14,010 (23.0)	5.81 (5.42, 6.20)		3.34 (3.04, 3.64)		1.98 (1.75, 2.21)		0.25 (0.17, 0.33)		0.10 (0.05, 0.15)	
12–14	15,773 (25.9)	8.01 (7.59, 8.44)		4.98 (4.64, 5.32)		2.47 (2.22, 2.71)		0.26 (0.18, 0.34)		0.12 (0.07, 0.17)	
15–17	15,557 (25.5)	10.26 (9.78, 10.74)		6.47 (6.08, 6.85)		3.18 (2.90, 3.45)		0.31 (0.22, 0.40)		0.13 (0.07, 0.18)	
Area			0.004		0.053		0.009		0.076		0.004
Urban	29,845 (49.0)	6.62 (6.34, 6.91)		4.08 (3.86, 4.31)		2.00 (1.84, 2.16)		0.29 (0.23, 0.36)		0.07 (0.04, 0.10)	
Rural	31,085 (51.0)	7.22 (6.93, 7.51)		4.40 (4.17, 4.63)		2.31 (2.14, 2.48)		0.22 (0.17, 0.27)		0.15 (0.11, 0.19)	
Seven Major Regions			<0.001		<0.001		<0.001		0.002		0.282
North	9,060 (14.9)	9.40 (8.80, 10.01)		5.66 (5.19, 6.14)		3.05 (2.69, 3.40)		0.36 (0.24, 0.49)		0.17 (0.08, 0.25)	
Northeast	8,986 (14.7)	5.07 (4.62, 5.53)		3.14 (2.78, 3.50)		1.40 (1.16, 1.65)		0.34 (0.22, 0.47)		0.08 (0.02, 0.14)	
East	8,956 (14.7)	8.14 (7.57, 8.71)		4.76 (4.32, 5.20)		2.81 (2.47, 3.16)		0.29 (0.18, 0.40)		0.09 (0.03, 0.15)	
Central	8,815 (14.5)	5.74 (5.25, 6.23)		3.55 (3.16, 3.94)		1.83 (1.55, 2.11)		0.12 (0.05, 0.20)		0.10 (0.04, 0.17)	
South	7,606 (12.5)	4.79 (4.31, 5.27)		3.12 (2.73, 3.51)		1.37 (1.11, 1.63)		0.13 (0.05, 0.21)		0.05 (0.00, 0.10)	
Southwest	8,772 (14.4)	9.03 (8.43, 9.63)		5.88 (5.39, 6.37)		2.49 (2.16, 2.81)		0.33 (0.21, 0.45)		0.15 (0.07, 0.23)	
Northwest	8,735 (14.3)	5.99 (5.49, 6.48)		3.41 (3.03, 3.79)		2.04 (1.74, 2.33)		0.19 (0.10, 0.29)		0.13 (0.05, 0.20)	
Total	60,930 (100.0)	6.93 (6.73, 7.13)		4.24 (4.08, 4.40)		2.16 (2.04, 2.27)		0.26 (0.22, 0.30)		0.11 (0.08, 0.14)	

Abbreviation: *CI*=confidence interval.

incidence of fractures across all age groups and regions, aligning with findings from prior research (*5*,*7*). Notably, this disparity widens beginning at the age of nine. This trend may be attributed to male children typically engaging in more vigorous and high-risk physical activities, thus increasing their susceptibility to fractures. Furthermore, our data indicate that fractures are most prevalent among males aged 10–13 and females aged 10–12. This pattern is supported by a comprehensive survey conducted in Beijing, which also identified the highest fracture incidence within the same age range for males (*7*). The differences in fracture rates among age groups likely reflect the stages of skeletal development, with fractures occurring most frequently during adolescence — a period characterized by rapid changes in bone mineral density,

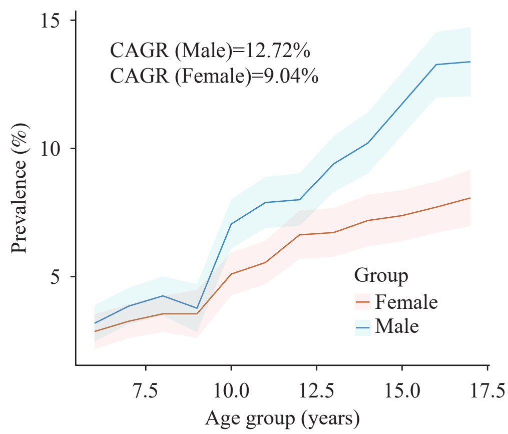

FIGURE 1. Prevalence of fractures with 95% confidence intervals by age and gender among children and adolescents aged 6–17 years in China, 2019–2021.
Note: The compound annual growth rate (CAGR) was calculated as the twelfth root of the total fracture prevalence rate among 6–17 year olds. The Cochran-Armitage Trend Test yielded a *P*<0.001.

geometry, and microarchitecture (*8*). Additionally, the higher bone elasticity in younger children and greater bone strength in older children contribute to lower fracture prevalences in these age groups.

Childhood fractures demonstrate notable regional disparities in China, with a higher incidence in rural areas compared to urban areas (7.22% *vs.* 6.62%). In economically disadvantaged rural regions, the prevalence of such injuries can be attributed to children's vulnerability to unbalanced diets or nutrient deficiencies that potentially compromise bone health (*9*). Additionally, a significant number of children in rural areas, often left unsupervised due to their parents' absence, face an increased risk of accidental injuries or fractures (*10*). This study is the first to elucidate regional variations in childhood fractures across seven major regions. Further research is warranted to investigate the factors influencing childhood fractures in different regions.

The prevalence of childhood fractures varies significantly across different anatomical sites. Over half of all fractures occur in the upper limbs, with a notably higher incidence in males (66%). A cohort study in Beijing revealed that fractures of the upper limb comprise approximately 65.9%–73.3% of fractures among children aged 6–16 years (*7*). Accelerated remodeling of the metaphysis in the forearms of children can lead to a temporary reduction in bone mass, thereby increasing the risk of fractures. Additionally, the frequent use of upper limbs in sports activities and their critical role in self-protection during unintentional injuries contribute to the higher prevalence of fractures in upper limbs.

This study was subject to some limitations. First, the age at which fractures occurred was determined based on questionnaire responses, which may introduce recall

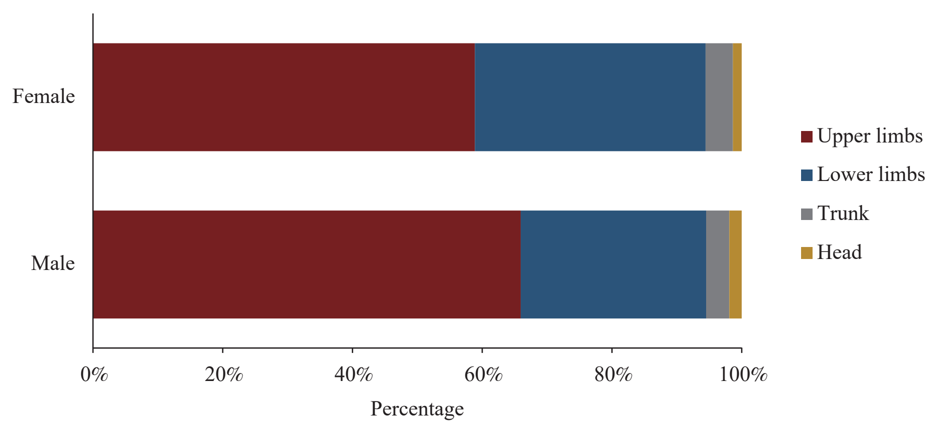

FIGURE 2. Composition of the percentage of different fracture sites by gender in children and adolescents.

bias. Second, the cross-sectional nature of this study precludes the calculation of fracture incidence; therefore, future cohort studies are advised.

In conclusion, childhood fractures represent a significant public health issue in China. Greater emphasis should be placed on children from rural areas and males in middle childhood. There is a need to enhance bone safety education for both children and their guardians to raise awareness about fracture prevention. Additional research is necessary to investigate potential factors influencing fractures among community children.

Conflicts of interest: No conflicts of interest.

Acknowledgements: We extend our gratitude to the project teams at the China CDC, provincial CDCs, county/district CDCs, local school staff, and all participants.

Funding: This work was supported by the Science and Technology Fundamental Resources Investigation Program of China (2017FY101105).

doi: 10.46234/ccdcw2024.174

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Submitted: April 24, 2024; Accepted: June 19, 2024

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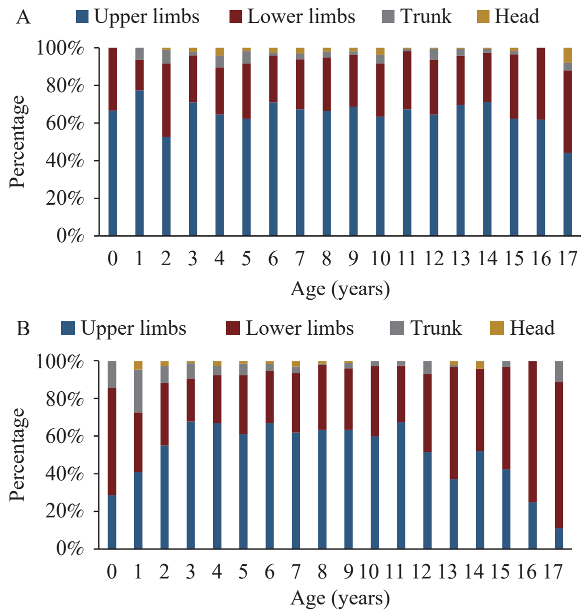
SUPPLEMENTAL MATERIAL



SUPPLEMENTARY FIGURE S1. Composition of fracture sites by percentage among children and adolescents aged 6–17 years. (A) Proportion of fractures in males. (B) Proportion of fractures in females.
Note: The x-axis represents the age at which a fracture occurs, and the y-axis represents the proportion in percentages.

Preplanned Studies

Establishing and Validating Refractive Error Reference Values for Myopia Prediction Among Children Aged 6–12 Years — Jiangsu Province, China, 2018–2023

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Summary

What is already known about this topic?

Previously, it has been proved that a simplified model that uses refraction error value provides a robust and efficient means of predicting myopia for non-myopic students. Intervention targeting non-myopic children with alert refraction errors (or insufficient hyperopia reserve) holds significant importance in reducing the incidence rate of myopia.

What is added by this report?

This study, comprising two phases (surveillance and cohort studies), was aiming to pinpoint the precise refractive error value for the onset of myopia prediction among non-myopic children in Jiangsu Province.

What are the implications for public health practice?

First, when conducting myopia screenings using pupil dilation for non-myopic populations: the cycloplegic 50th percentile refractive error emerges as a more precise predictive indicator. Second, when conducting myopia screenings without pupil dilation: this study advocates for the incorporation of axial length (AL) and corneal curvature (CC) values as supplementary indicators in screenings.

Myopia is a widespread visual condition affecting individuals worldwide, with a notably high prevalence among Chinese students. In regions with a high prevalence of myopia, such as China, utilizing highly sensitive indicators for precise myopia prediction among non-myopic populations has significant public health implications. The prevalence of myopia in Chinese children and adolescents is alarmingly high, with rates of 72% and 81% among middle school (ages 11–13 years) and high school (ages 14–17 years) students, respectively, resulting in an overall prevalence of approximately 54%. Myopia not only causes various vision-threatening ocular complications, such as cataracts, glaucoma, and blindness, but also detrimentally affects children's physical fitness, mental health, and academic performance (*1*). The prevalence of myopia and vision impairment is high among school students in Eastern China, and by the year 2050, the estimated population of myopic individuals will be 8,568,305 [95% confidence interval (*CI*): 8,398,977, 8,737,633] for those aged 7–12 years and 15,766,863 (95% *CI*: 15,744,826, 15,788,900) for those aged 13–18 years (*2*). Precise myopia prediction and tailored health intervention reminders can encourage parents and schools to take a serious stance on myopia (*3*). A percentage-based approach has previously been adopted to establish alert thresholds for non-myopic children (*4*). A cross-sectional and cohort study was initiated in Jiangsu Province in 2018 among non-myopic students. Previous research has found that the incidence of myopia decreases with increasing baseline hyperopic reserve, suggesting that intervention for pre-myopic children with alert refraction errors (or insufficient hyperopia reserve) is important in reducing the incidence of myopia (*5*). To further enhance the accuracy and effectiveness of preventive measures, establishing more accurate alert thresholds (refraction error values) to prevent the onset of childhood myopia is necessary (*6*).

A surveillance study was conducted using data from the Student Health Surveillance program in Jiangsu Province. Data, including the 25th–95th percentiles of refractive error, were collected from multiple cities during three occasions spanning the 2018–2019 to 2022–2023 academic years. Two to three cities from three tiers of economic development in Jiangsu Province were selected: Southern (Suzhou City, Zhenjiang City), Central (Nantong City, Yangzhou City, Taizhou City), and Northern (Xuzhou City, Yancheng City). Subsequently, two to four elementary schools were chosen from each selected city. The study included all students, including non-myopic students, whose parents provided informed consent. More than 3,000 non-myopic students aged 6–12 years were included in each sampling instance using a stratified sampling method to ensure representation. Inclusion criteria were: 1) Chinese Han nationality students, aged 6 to 10 years from grades 1 to 3; 2) no other severe diseases, such as hepatitis, nephritis, and eye disease; 3) provision of informed consent from parents/guardians; and 4) school-based participant to prevent loss to follow-up. Students with baseline myopia were excluded. A total of 11,013 non-myopic students received ophthalmic examinations pre- and post-dilation. The study protocol was approved by the Institutional Review Board of Ethics committee of Jiangsu Provincial Center for Disease Control and Prevention (JSJK2021-B08-02) (*4*).

A cohort study was conducted to validate the myopia prediction model using data from the Eastern China Student Cohort study in Pei County, Changshu City, Yizheng City, and Dongtai City. This prospective implementation study gradually included project points in stages and levels (*7*). In total, 3,204 non-myopic students were included: 1) 1,176 students from a four-year cohort study in Pei County; 2) 740 students from a three-year cohort study in Changshu City; and 3) 312 and 976 students, respectively, from two-year cohort studies in Yizheng City and Dongtai City. Data were collected through physical examinations [axial length (AL), corneal curvature (CC), and post- and pre-cycloplegic refractive error] and parental questionnaires [behaviors (parental myopia, near work, outdoor activity, sleep, and sugar consumption) and basic profiles]. Statistically significant differences (P<0.05) were observed between students with myopia onset after one year of follow-up and those without influencing factors such as gender, AL, parental myopia, and near work (homework duration). These statistically significant variables were then applied to the machine learning model. Model 1 included age, gender, parental myopia, near work, and follow-up years. Model 2 included the same variables as Model 1 with the addition of AL and CC (Figure 1 and Table 1).

Ophthalmic examinations were conducted by skilled nurses and doctors. Students participating in the myopia screening underwent refractive examinations using a fully automated computerized refractometer (TOPCON RM800/KR800) following pupil dilation with compound tropicamide eye drops to determine their refractive status. AL and CC were assessed using NIDEK AL-Scan Quality Control for the survey supervised by a dedicated professional. The screening equipment and refractometer conformed to ISO-10342 standards for ophthalmic instruments (*8*–*9*). Myopia was defined as cycloplegic spherical equivalent refraction (SER) ≤–0.50 D (*10*). Non-myopic students were defined as students with cycloplegic SER >–0.50 D. Refraction error percentiles were calculated using

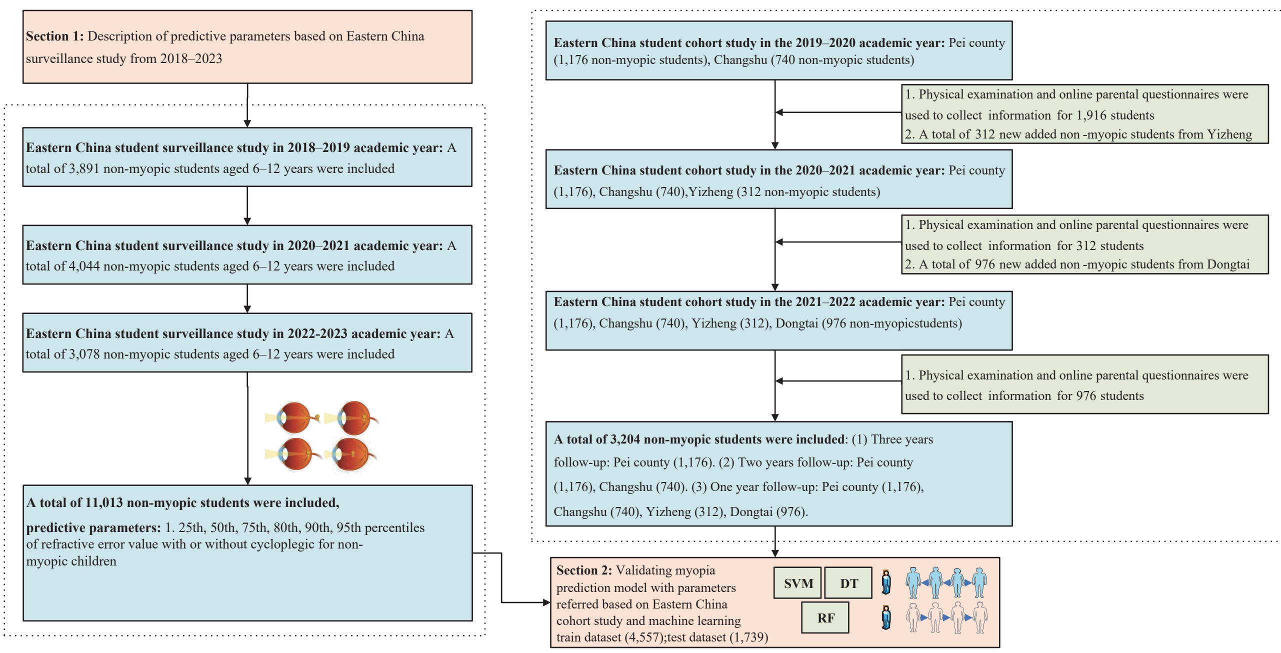

FIGURE 1. Flowchart of student surveillance and cohort study in Jiangsu Province spanning the academic years from 2018–2019 to 2022–2023.

TABLE 1. Distribution of baseline characteristics among non-myopic students from a cohort study (*n*=3,204).

Variable	Non-myopic students after one year follow-up (*n*=2,327)	Students with myopia onset after one year follow-up (*n*=877)	χ^2/T/Z	*P*
Age	8.0±1.0	8.0±1.0	1.39	0.166
Female students, *n* (%)	989 (42.5)	445 (50.7)	17.49	<0.001
Vision (R)	5.0±0.1	5.0±0.1	1.53	0.126
Axial length (R), mm	22.9±0.8	23.2±0.7	10.20	<0.001
Cycloplegic SE (R), D	0.9 (0.5–1.1)	0.1 (−0.1–0.5)	27.81	<0.001
Corneal curvature (R), D	43.0±1.5	43.1±1.4	2.07	0.039
Height, cm	129.2±7.9	129.2±7.8	0.07	0.945
Weight, kg	29.8±8.1	30.0±8.0	0.49	0.623
Parental myopia, *n* (%)				
Father myopia	593 (25.5)	307 (35.0)	28.59	<0.001
Mother myopia	714 (30.7)	384 (43.8)	48.54	<0.001
Near work, *n* (%)				
Sitting posture (the chest is one fist distance away from the desk)	1,500 (64.5)	567 (64.7)	0.10	0.920
Sitting posture (the eyes are one foot away from the textbook)	1,432 (61.5)	510 (58.2)	3.06	0.080
Sitting posture (the fingertips are one inch away from the pen tip)	1,142 (49.1)	429 (48.9)	0.01	0.936
Duration of monocular usage (<1 h)	1,522 (65.4)	568 (64.8)	0.12	0.735
Duration of homework (<2 h)	1,933 (83.1)	694 (79.1)	6.68	0.010
Eye exercise twice per day	2,206 (94.8)	829 (94.5)	0.10	0.758
Outdoor activity (>2 h), *n* (%)	262 (11.3)	95 (10.8)	0.12	0.732
Sleep duration (h)	9.2±0.8	9.2±0.8	0.05	0.957
Sugar drink per week, *n* (%)	688 (29.6)	278 (31.7)	1.38	0.241
Sugar food per week, *n* (%)	185 (8.0)	60 (6.8)	1.11	0.292

Abbreviation: SE=spherical equivalent.

data on cycloplegic and non-cycloplegic refraction error from the survey, stratified by gender and age among non-myopic students. This calculation was performed for the 25th, 50th, 75th, 80th, 90th, and 95th percentiles. The Z-score was calculated for each data set, taking into account location (median), scale (approximate coefficient of variation), skewness (power transformation for symmetry), and kurtosis (degrees of freedom or power exponential parameter) to represent the distribution of each age–gender group (*11*). For machine learning analysis, 70% of the dataset was dedicated to model training, with the remaining 30% reserved for evaluating model performance. This study evaluated four prominent machine learning models: support vector machine (SVM), random forest (RF), and decision tree (DT). The key performance metric was the area under the curve (AUC) derived from the receiver operating characteristic (ROC) curve. To improve result reliability, a 95% *CI* for AUC was computed.

The 50th percentile refractive error values with cycloplegia for non-myopic boys were 0.63 D at age 6 years, decreasing to 0.50 D at 7 years, 0.38 D at 8 years, and 0.25 D at 10 years, and 0.16 D by age 12 years. This value remained consistent at 0.38 D between ages 8 and 9 years and at 0.25 D between ages 10 and 11 years. Without cycloplegia, the 50th percentile refractive error values for non-myopic boys were 0.0 at ages 6 and 7 years, decreasing to −0.13 D at ages 8 and 9 years, −0.25 D at age 10 years, and −0.38 D at ages 11 and 12 years. Detailed information is shown in Table 2.

Myopia prediction performance based on machine learning: First, for students in Jiangsu Province, the amalgamated predictive model encompassing the “50th percentile of refractive error with cycloplegic,” “questionnaire (age, gender, parental myopia, and near work),” and “AL and CC” demonstrated superior predictive efficacy, yielding an AUC of 0.83, 0.85, and 0.80. The 50th percentile of AUC values across the

TABLE 2. Percentiles of refractive error value with and without cycloplegia for non-myopic children sorted by age and gender from a surveillance study in Jiangsu Province, China, 2018–2023.

Age, years	Percentiles of cycloplegic refractive error	Male, D	Female, D	Percentiles of non-cycloplegic refractive error	Male, D	Female, D
6	25th	0.13	0.13	25th	−0.25	−0.25
	50th	0.63	0.63	50th	0.00	0.00
	75th	1.00	1.13	75th	0.38	0.38
	80th	1.13	1.25	80th	0.38	0.50
	90th	1.38	1.50	90th	0.63	0.75
	95th	1.75	1.88	95th	0.88	1.00
7	25th	0.13	0.13	25th	−0.38	−0.38
	50th	0.50	0.63	50th	0.00	0.00
	75th	0.88	1.00	75th	0.35	0.25
	80th	1.00	1.13	80th	0.38	0.38
	90th	1.25	1.38	90th	0.63	0.63
	95th	1.50	1.63	95th	0.88	0.88
8	25th	0.00	0.00	25th	−0.50	−0.50
	50th	0.38	0.38	50th	−0.13	−0.13
	75th	0.75	0.75	75th	0.13	0.13
	80th	0.88	0.88	80th	0.25	0.25
	90th	1.13	1.13	90th	0.50	0.50
	95th	1.50	1.50	95th	0.75	0.71
9	25th	0.00	0.00	25th	−0.50	−0.50
	50th	0.38	0.38	50th	−0.13	−0.18
	75th	0.75	0.72	75th	0.13	0.13
	80th	0.88	0.80	80th	0.25	0.13
	90th	1.13	1.12	90th	0.50	0.38
	95th	1.50	1.38	95th	0.75	0.63
10	25th	−0.13	−0.13	25th	−0.50	−0.50
	50th	0.25	0.25	50th	−0.25	−0.38
	75th	0.63	0.63	75th	0.13	0.00
	80th	0.63	0.75	80th	0.13	0.13
	90th	1.00	1.00	90th	0.44	0.38
	95th	1.25	1.36	95th	0.63	0.63
11	25th	−0.13	−0.13	25th	−0.50	−0.50
	50th	0.25	0.13	50th	−0.38	−0.38
	75th	0.50	0.63	75th	0.00	0.00
	80th	0.63	0.75	80th	0.13	0.13
	90th	0.88	1.00	90th	0.38	0.38
	95th	1.25	1.33	95th	0.38	0.63
12	25th	−0.13	−0.13	25th	−0.50	−0.50
	50th	0.16	0.13	50th	−0.38	−0.50
	75th	0.50	0.44	75th	0.00	−0.13
	80th	0.63	0.63	80th	0.13	0.00
	90th	0.88	0.88	90th	0.38	0.25
	95th	1.25	1.19	95th	0.38	0.54

three machine learning models (SVM, RF, and DT) surpassed those of Model 1 and Model 2, and these differences were statistically significant (P<0.05). Second, the AUC values for the combination of "50th percentile of refractive error without cycloplegic" + "questionnaire" across the three machine learning models (SVM, RF, and DT) all outperformed that of Model 1 (P<0.05). Furthermore, Model 2 demonstrated higher AUC values than Model 1 for SVM, RF, and DT (P<0.05) (Table 3). If a student attained the 50th percentile refractive error with cycloplegia, the likelihood of developing myopia within the subsequent year was 7-fold higher for boys and 4.7-fold higher for girls compared with students who did not reach the 50th percentile refractive error (Figure 2).

DISCUSSION

When conducting myopia screenings using pupil dilation for non-myopic populations, the cycloplegic 50th percentile refractive error emerges as a more precise predictive indicator. A series of age- and gender-based SE threshold values were established to predict myopia in Chinese children aged 6 to 12 years. This aligns with the findings of a previous cross-sectional study (*4*), in which the 50th prediction model (RF, SVM, DT) achieved the best AUC values. When non-myopic students reach the 50th percentile cycloplegic refractive error value, the likelihood of myopia onset in the subsequent year increases 7-fold for boys and 4.7-fold for girls, compared to the control group. The proposed precise refractive error values aim to encourage schools and parents to heighten their awareness to prevent myopia onset. Targeted public intervention measures will also be promptly directed at these children. In China, non-dilated screening methods are widely deployed in large-scale population screenings due to their practicality and efficiency. This study advocates for incorporating AL and CC as supplementary indicators in screenings, augmenting the sole use of noncycloplegic refractive error.

The 50th reference value for non-myopic individuals determined in this study has practical utility for subsequent precision interventions in Jiangsu Province. Myopia prediction using baseline refraction or biometric data dates back to 1999, when Zadnik et al. (*12–13*) attempted to forecast the onset of juvenile myopia. This study incorporated behavioral factors

TABLE 3. Myopia prediction performance based on machine learning.

Predictive parameters (Train∶Test=7∶3)	AUC (SVM)*	AUC (RF)*	AUC (DT)*
Model 1*	0.66 (0.63–0.68)	0.72 (0.69–0.74)	0.63 (0.61–0.65)
Model 1+0th refractive error with cycloplegic	0.68 (0.65–0.71)	0.72 (0.69–0.74)	0.63 (0.61–0.65)
Model 1+25th refractive error with cycloplegic	0.78 (0.75–0.80)	0.81 (0.79–0.84)	0.77 (0.74–0.79)
Model 1+50th refractive error with cycloplegic	0.80 (0.78–0.82)	0.84 (0.82–0.86)	0.80 (0.77–0.82)
Model 1+75th refractive error with cycloplegic	0.75 (0.72–0.77)	0.78 (0.76–0.81)	0.77 (0.74–0.79)
Model 1+0th refractive error without cycloplegic	0.68 (0.65–0.71)	0.72 (0.69–0.74)	0.63 (0.61–0.65)
Model 1+25th refractive error without cycloplegic	0.70 (0.68–0.73)	0.75 (0.73–0.77)	0.64 (0.62–0.66)
Model 1+50th refractive error without cycloplegic	0.72 (0.69–0.74)	0.77 (0.75–0.79)	0.70 (0.68–0.73)
Model 1+75th refractive error without cycloplegic	0.70 (0.68–0.73)	0.77 (0.74–0.79)	0.64 (0.61–0.66)
Model 2†	0.78 (0.75–0.80)	0.78 (0.75–0.80)	0.69 (0.67–0.72)
Model 2+0th refractive error with cycloplegic	0.78 (0.75–0.80)	0.78 (0.76–0.81)	0.69 (0.67–0.72)
Model 2+25th refractive error with cycloplegic	0.81 (0.79–0.84)	0.84 (0.82–0.86)	0.77 (0.74–0.79)
Model 2+50th refractive error with cycloplegic	0.83 (0.81–0.85)	0.85 (0.83–0.86)	0.80 (0.77–0.82)
Model 2+75th refractive error with cycloplegic	0.80 (0.78–0.82)	0.81 (0.79–0.83)	0.77 (0.74–0.79)
Model 2+0th refractive error without cycloplegic	0.78 (0.75–0.80)	0.78 (0.76–0.81)	0.69 (0.67–0.72)
Model 2+25th refractive error without cycloplegic	0.78 (0.76–0.80)	0.80 (0.78–0.82)	0.71 (0.69–0.74)
Model 2+50th refractive error without cycloplegic	0.78 (0.76–0.81)	0.80 (0.78–0.83)	0.70 (0.67–0.72)
Model 2+75th refractive error without cycloplegic	0.78 (0.76–0.80)	0.80 (0.78–0.82)	0.71 (0.69–0.74)

Abbreviation: SVM=support vector machine; RF=random forest; DT=decision tree; AUC=area under the curve; AL=axial length.
* Model 1: Baseline information from questionnaires: age, gender, parental myopia, near work, follow-up years (1 to 3);
† Model 2: Model1+ biometric parameters including AL and corneal curvature.

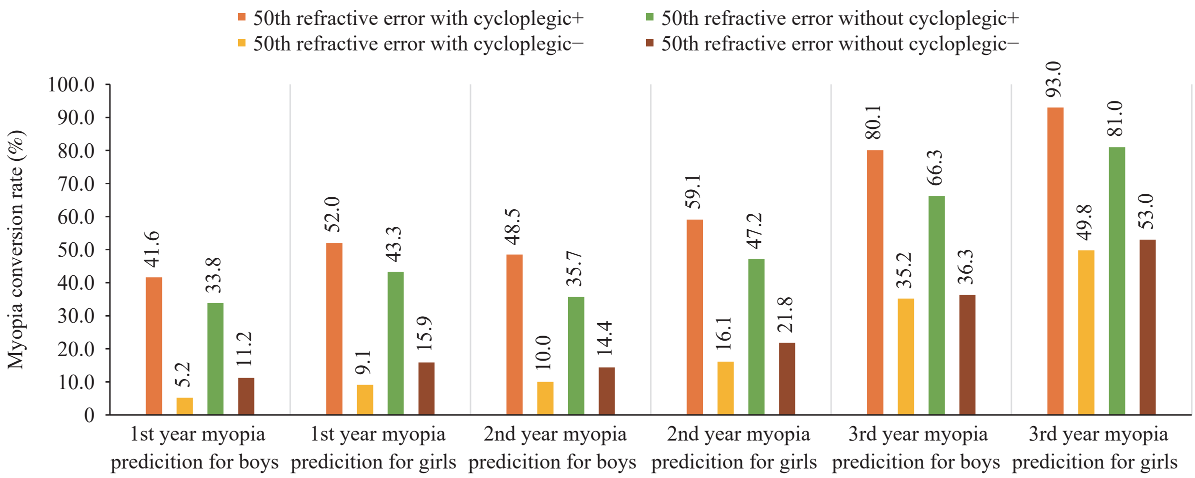

FIGURE 2. Predicting the future myopia conversion rate among non-myopic students based on the 50th percentiles of refractive error values in Jiangsu Province, China, 2018–2023.

such as parental myopia and near work; nevertheless, their predictive effectiveness was less than satisfactory. Using SCORM data, Chua et al. (*14*) found that the age of myopia onset alone can effectively predict high myopia (AUC=0.85). Incorporating additional factors, such as school attendance and weekly book reading, only slightly improved the prediction accuracy (AUC=0.87).

In China, the governmental approach to school screening predominantly relies on noncycloplegic refractions, and the Chinese Ministry of Health derives myopia prevalence reports from these school-screening assessments. Widely adopted in large-scale population screenings due to their practicality and efficiency, nondilated screening methods have inherent limitations, particularly in evaluating refractive errors such as myopia. With the SVM machine learning model, the predictive performance (AUC=0.78) significantly surpasses that of the 50th percentile noncycloplegic refractive error (AUC=0.72) (P<0.05). Hence, incorporating AL and CC in nondilated screenings warrants consideration. However, significant biases exist in current screening programs when evaluating younger students. This study provides objective data on two screening modes: dilated and nondilated. In areas where feasible, such as economically developed regions, large-scale implementation of dilated screening may be possible.

This study was subject to some limitations. First, the influence of gene-environment interactions on myopia prediction was not explored. Second, because of limitations in longitudinal data collection, this study only made predictions for 1–3 years. Follow-up with this cohort is planned for the later stages.

Conflicts of interest: No conflicts of interest.

Acknowledgements: Professor Genming Zhao, Professor Fengyun Zhang, Professor Jun Ma, Professor Fangbiao Tao, Professor Hu Liu, and Professor Hongsheng Bi; We also thank to over 100 on-site collaborators and educators from various centers of this project.

Funding: Jiangsu Provincial Science and Technology Resource Coordination Service Platform for open research project (TC2022B023).

doi: 10.46234/ccdcw2024.175

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Submitted: December 01, 2023; Accepted: March 18, 2024

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Preplanned Studies

Hearing Loss and Depressive Symptoms Among Community-Dwelling Older Adults — Liaoning, Henan, and Guangdong Provinces, China, 2019–2020

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Summary

What is already known about this topic?

More than half of Chinese older adults over 60 are suffering from hearing loss (HL), which might increase the risk of depressive symptoms.

What is added by this report?

The results indicated a significant association between severe or profound HL and depressive symptoms, characterized by notable age and gender disparities, particularly among women aged 60–74 years old.

What are the implications for public health practice?

Timely intervention and treatment for elderly individuals with HL, particularly younger female elders suffering from severe or profound HL, are pivotal in reducing depressive symptom rates and are key policy considerations.

Hearing loss (HL), a highly prevalent and undertreated disorder in older adults, affects over 60% of the elderly population in China (*1*). A national survey in China revealed that older adults have a higher prevalence of depression compared to other age groups (*2*). HL significantly impacts communication and participation in social activities, potentially leading to social isolation and negatively affecting physical and mental health. Furthermore, research suggests that HL increases the risk of depression (*3*). Scinicariello's study demonstrated age and gender disparities in the association between moderate to severe HL and depressive symptoms among older adults in the United States (*4*). However, there is limited research on this association in older Chinese adults. This study aims to explore the relationship between severe or profound HL and depressive symptoms in the general population, focusing on age and gender differences. Data were obtained from the Prevention and Intervention on Neurodegenerative Disease for Elderly in China (PINDEC) project, which focuses on building capacity for the prevention and intervention of Alzheimer's disease (AD) and Parkinson's disease (PD), as well as other health conditions. This study included 9,865 community-dwelling older adults aged 60 years and older from three provinces in China. The results indicate that younger elderly individuals aged 60–74 are a high-risk group for the association between severe or profound HL and depressive symptoms. Additionally, there is a significant correlation between severe or profound HL and depressive symptoms among elderly women aged 60–74. This study shows that elderly people with severe or profound HL have a significantly increased risk of depressive symptoms. Therefore, developing a national strategy for preventing and managing HL in the elderly population is crucial to reducing the risk of depressive symptoms.

The PINDEC project considered both the degree of aging and balanced geographical distribution when initiating its 2019–2020 survey of community-based residents aged 60 and above in three regions: Liaoning, Henan, and Guangdong provinces. The stratified multi-stage cluster sampling process involved several steps. First, two or three cities were randomly selected from each province. Second, one county and one district were randomly selected from each city. Third, one subdistrict in urban areas and one township in rural areas were selected from each county/district using probability proportionate to size sampling. Finally, 4–8 administrative villages or neighborhood communities were randomly selected from each subdistrict/township using cluster sampling until the desired sample size (1,000 participants) was reached. A total of 12,369 older adults aged 60 and above were initially included (*5*). After excluding participants with missing key variables or who refused to participate in psychological questionnaires and hearing tests, 9,865 respondents remained in the study (Supplementary Figure S1, available at https://weekly.chinacdc.cn/). The study was approved by the Ethnics Committee of the National Center for Chronic and Non-Communicable Disease Control and Prevention, China CDC (Ref. no.: 201902). All participants were assigned informed consent forms.

HL was measured using the four-frequency air conduction pure-tone average (PTA) in the better ear at 500, 1,000, 2,000, and 4,000 Hz and reported continuously in decibels (dB). Lower hearing thresholds indicated better hearing, while higher thresholds indicated worse hearing. HL severity was defined using the following categories: normal HL (0 to 25 dB), mild HL (26 to 40 dB), moderate HL (41 to 60 dB), and severe or profound HL (61 dB or worse) (*6*). The Patient Health Questionnaire-9 (PHQ-9) was used to screen for depressive symptoms. PHQ-9 scores range from 0 to 27, and participants with scores of 5 or above were identified as having depressive symptoms (*7*).

Categorical variables were described using frequencies and proportions. Differences between subgroups were analyzed using the chi-square test. Multivariable logistic regression models were used to assess the association between depressive symptoms and HL, adjusting for covariates (demographic variables, behavioral factors, and cardiovascular disease). Statistical significance was set at $P<0.05$. All statistical analyses were performed using R software (Version 4.0.5; R Foundation for Statistical Computing, Vienna, Austria).

A total of 9,865 adults (mean age: 68.92±6.46 years) were included in this study (Table 1). Of these, 1,640 (16.62%) met the criteria for depressive symptoms. The prevalence of depressive symptoms was 15.12%, 16.47%, 18.22%, and 23.00% for participants with normal HL, mild HL, moderate HL, and severe or profound HL, respectively ($P<0.001$).

As HL severity increased, a statistically significant trend toward higher levels of depressive symptoms emerged in both male and female older adults ($P<0.001$). However, when stratified by age and gender, a progressively higher rate of depressive symptoms with increasing HL was observed only among women aged 60–74 years (Table 2).

Multivariable logistic regression analyses revealed a significant association between severe or profound HL and depressive symptoms after adjusting for multiple variables [odds ratio (*OR*): 1.52, 95% confidence interval (*CI*): 1.15, 2.01]. This association was also observed among participants aged 60–74 years (*OR*: 1.50, 95% *CI*: 1.04, 2.16). Stratified by gender, the *OR* for severe or profound HL was 1.56 (95% *CI*: 1.00, 2.43) for males in the whole population and 1.60 (95% *CI*: 1.01, 2.56) for females in the 60–74 age group (Table 3).

DISCUSSION

This study analyzed the relationship between HL and depressive symptoms among community-dwelling older people aged 60 years and over in three regions of China (Liaoning, Henan, and Guangdong provinces). The results showed that severe or profound HL was a risk factor for depressive symptoms and that gender was a potential moderator of this association. After stratifying by age group, a positive correlation was observed between HL and depressive symptoms among females aged 60 to 74 years. This suggests that early intervention and treatment of HL in older adults, especially women over 60, to prevent further deterioration may promote psychological well-being and improve quality of life in later life.

Numerous studies have established a correlation between HL and depressive symptoms (*8*). In this study, after accounting for a wide variety of confounders, including demographics, behavioral variables, and cardiovascular risk factors, a positive association between severe or profound HL and depressive symptoms was found (*OR*: 1.52, 95% *CI*: 1.15, 2.01). Behavioral factors may explain this association in older populations (*9*). Hearing is crucial for spoken language communication, so HL is closely linked to social problems. People with HL are more likely to isolate themselves from society, experience social isolation, and have smaller social circles, factors that have been independently associated with depressive symptoms.

This study further explored age differences and found a positive association between severe or profound HL and depressive symptoms among elderly individuals aged 60–74. However, no significant association was observed in those aged 75 and above. One possible explanation is that individuals aged 60–74 are still actively engaged in work and social activities, and HL significantly impacts these aspects of their lives, thereby increasing the risk of depressive symptoms. Conversely, older adults may have adapted to HL over time and developed more effective coping strategies. They may be more proficient in utilizing visual cues or using hearing aids compared to those aged 60–74.

This study also indicated that within the 60–74 age group, women are more prone to depressive symptoms

TABLE 1. Prevalence of depressive symptoms for older adults by characteristics in three provinces in China.

Characteristics	*N* (%)	Depressive symptoms		
		Cases	Prevalence [% (95% *CI*)]	*P*
Total	9,865 (100.00)	1,640	16.62 (15.89, 17.36)	
Age groups, years				<0.001
60–64	2,925 (29.65)	426	14.56 (13.29, 15.84)	
65–69	3,024 (30.65)	473	15.64 (14.35, 16.94)	
70–74	2,015 (20.43)	336	16.67 (15.05, 18.30)	
75–79	1,098 (11.13)	239	21.77 (19.33, 24.21)	
≥80	803 (8.14)	166	20.67 (17.87, 23.47)	
Sex				<0.001
Male	4,184 (42.41)	496	11.85 (10.88, 12.83)	
Female	5,681 (57.59)	1,144	20.14 (19.09, 21.18)	
Area type				<0.001
Urban	4,094 (41.50)	593	14.48 (13.41, 15.56)	
Rural	5,771 (58.50)	1,047	18.14 (17.15, 19.14)	
Education				<0.001
Illiteracy	2,545 (25.80)	576	22.63 (21.01, 24.26)	
Primary school	3,752 (38.03)	582	15.51 (14.35, 16.67)	
Junior high school	2,459 (24.93)	341	13.87 (12.50, 15.23)	
Senior high school and above	1,109 (11.24)	141	12.71 (10.75, 14.67)	
Marital status				<0.001
Non-widowed	7,876 (79.84)	1,231	15.63 (14.83, 16.43)	
Widowed	1,989 (20.16)	409	20.56 (18.79, 22.34)	
Provinces				<0.001
Liaoning	3,262 (33.07)	610	18.70 (17.36, 20.04)	
Guangdong	3,336 (33.12)	364	11.14 (10.06, 12.22)	
Henan	3,267 (33.82)	666	19.96 (18.61, 21.32)	
Neighborhood communication				<0.001
Almost never	1,811 (18.36)	369	20.38 (18.52, 22.23)	
Regular communicate	8,054 (81.64)	1,271	15.78 (14.98, 16.58)	
Social activities				<0.001
Almost never	6,847 (69.41)	1,311	19.15 (18.22, 20.08)	
Regular join activities	3,018 (30.59)	329	10.90 (9.79, 12.01)	
Daily exercise				<0.001
No regular exercise	2,290 (23.21)	502	21.92 (20.23, 23.62)	
Regular exercise	7,575 (76.79)	1,138	15.02 (14.22, 15.83)	
Hypertension				<0.001
No	6,173 (62.57)	920	14.90 (14.02, 15.79)	
Yes	3,692 (37.43)	720	19.50 (18.22, 20.78)	
Diabetes				<0.001
No	8,607 (87.25)	1,367	15.88 (15.11, 16.65)	
Yes	1,258 (12.75)	273	21.70 (19.42, 23.98)	
Dyslipidemia				<0.001
No	8,333 (84.47)	1,245	14.94 (14.18, 15.71)	

Continued

Characteristics	*N* (%)	Depressive symptoms		
		Cases	Prevalence [% (95% *CI*)]	*P*
Yes	1,532 (15.53)	395	25.78 (23.59, 27.97)	
Hearing Loss				<0.001
Normal	3,029 (30.71)	458	15.12 (13.84, 16.40)	
Mild	4,687 (47.51)	772	16.47 (15.41, 17.53)	
Moderate	1,762 (17.86)	321	18.22 (16.42, 20.02)	
Severe or profound	387 (3.92)	89	23.00 (18.80, 27.19)	

Abbreviation: *CI*=confidence interval.

TABLE 2. Prevalence of depressive symptoms among Chinese older adults with different HL levels, by age group and sex.

Grades of hearing loss	Depressive symptoms					
	ALL		60–74 Years		≥75 Years	
	Male	Female	Male	Female	Male	Female
Normal HL	111 (10.28)	347 (17.80)	95 (9.58)	311 (17.25)	16 (18.18)	36 (24.66)
Mild HL	229 (11.31)	543 (20.40)	95 (9.58)	418 (19.14)	47 (12.74)	125 (26.15)
Moderate HL	119 (13.51)	202 (22.93)	73 (12.29)	113 (20.89)	46 (16.03)	89 (26.18)
Severe or profound HL	37 (18.69)	52 (27.51)	15 (16.30)	28 (27.45)	22 (20.75)	24 (27.59)
P	0.003	<0.001	0.126	0.023	0.176	0.968

Abbreviation: HL= hearing loss.

TABLE 3. Multivariable logistic regression analyses between depressive symptoms and HL for older adults in three provinces in China, by age group and sex.

Item	*OR* (95% *CI*)		
	All	60–74 years	≥75 Years
Grades of hearing loss			
Normal HL		Ref.	
Mild HL	1.05 (0.92, 1.20)	1.05 (0.91, 1.20)	0.90 (0.62, 1.29)
Moderate HL	1.16 (0.98, 1.38)	1.06 (0.87, 1.29)	0.89 (0.61, 1.30)
Severe or profound HL	1.52 (1.15, 2.01)*	1.50 (1.04, 2.16)*	1.07 (0.67, 1.71)
Male			
Normal HL		Ref.	
Mild HL	0.98 (0.76, 1.25)	1.07 (0.82, 1.40)	0.65 (0.34, 1.24)
Moderate HL	1.07 (0.79, 1.44)	1.16 (0.83, 1.62)	0.76 (0.39, 1.48)
Severe or profound HL	1.56 (1.00, 2.43)*	1.64 (0.88, 3.04)	1.13 (0.53, 2.42)
Female			
Normal HL		Ref.	
Mild HL	1.11 (0.95, 1.29)	1.11 (0.94, 1.31)	1.11 (0.71, 1.73)
Moderate HL	1.16 (0.94, 1.43)	1.18 (0.92, 1.50)	1.06 (0.67, 1.70)
Severe or profound HL	1.41 (0.99, 2.02)	1.60 (1.01, 2.56)*	1.14 (0.61, 2.14)

Note: Adjusting demographic variables including urban-rural status, educational level, province, and marital status; behavioral variables such as neighborhoods, social activities, and daily exercise; and cardiovascular risk factors such as hypertension, diabetes, and dyslipidemia. Ref. means the control group.
Abbreviation: HL=hearing loss; *OR*=odds ratio; *CI*=confidence interval.
* *P*<0.05.

associated with HL compared to men. Li (*10*) found that self-reported HL was linked to depressive symptoms in older women. Similarly, other research has shown that moderate to severe HL was associated with depressive symptoms among women aged 52–69 in the U.S. (*4*). This may be due to women generally being more expressive of their emotions and more sensitive to self-perception. These findings underscore the need for targeted public health interventions focusing on the mental health of older women. Comprehensive intervention strategies should account for gender differences and provide specialized psychological and social support services for older women, ultimately enhancing their social engagement and psychological resilience.

This study is subject to some limitations. As a cross-sectional study, it could not establish a causal relationship between depressive symptoms and HL. Although this study controlled for many confounding factors, certain variables (like the use of hearing aids) were not included due to data limitations, potentially affecting the results. Additionally, data from western and eastern provinces of China are missing, limiting the generalizability of the findings. Future research should include more regions.

In conclusion, this study demonstrates significant age and gender differences in the relationship between severe to profound HL and depressive symptoms. This relationship was particularly pronounced among women aged 60–74 years. Public health strategies should include more precise interventions tailored to different age and gender groups. For example, regular hearing screenings and mental health assessments should be conducted for women aged 60–74. Additionally, community health education programs can enhance awareness of HL and depressive symptoms among older adults and their families, promoting early detection and intervention to reduce the incidence of depressive symptoms. Furthermore, integrating regular auditory assessments and follow-up appointments ensures that hearing aids are properly adjusted and functioning optimally. Providing access to counseling services for both HL and depressive symptoms, as well as facilitating support groups, can offer emotional support and practical advice.

Conflicts of interest: No conflicts of interest.

Acknowledgements: All participants who took part in the project and doctors from collaborative hospitals, on-site work organization of primary medical and public health institutions, supervision and guidance by all experts during the project implementation process.

Funding: Supported by the Major Public Health Special Project of Ministry of Finance (131091106000150003).

doi: 10.46234/ccdcw2024.176

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Submitted: February 06, 2024; Accepted: July 22, 2024

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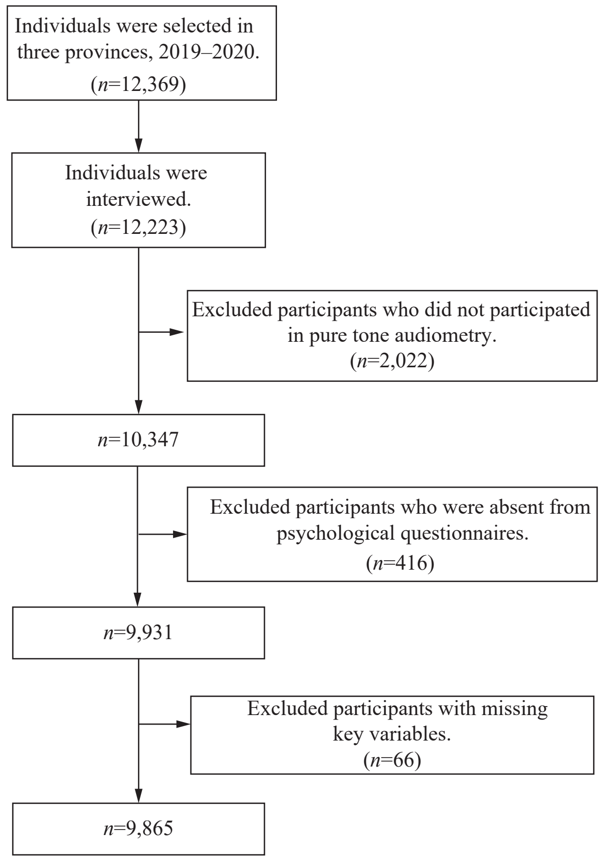
SUPPLEMENTARY MATERIAL



SUPPLEMENTARY FIGURE S1. The flowchart of the study sample.

Preplanned Studies

Hearing Loss and Cognitive Impairment Among Community-Dwelling Older Adults — Liaoning, Henan, and Guangdong Provinces, China, 2019–2020

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Summary

What is already known about this topic?

Many studies have shown that hearing loss (HL) is a risk factor for cognitive decline and dementia, but there are still limited studies on this association among Chinese older adults.

What is added by this report?

Based on the results of pure-tone audiometry tests, HL is associated with cognitive impairment in community-dwelling older adults. The odds ratios (*OR*s) were 1.23 (1.08–1.40) for mild HL, 1.55 (1.32–1.82) for moderate HL, and 1.87 (1.47–2.39) for severe or profound HL.

What are the implications for public health practice?

Enhanced public awareness of hearing protection is important for preventing cognitive impairment. It is advocated to promote the screening of HL and cognitive function assessment in elderly health examinations or management in primary care services.

Hearing loss (HL) and cognitive impairment are both highly prevalent neurological complications for older adults, affecting approximately 59% and 22% of older adults, respectively (*1*–*2*). A systematic review and meta-analysis showed that age-related HL was a possible biomarker and modifiable risk factor for cognitive impairment (*3*). However, to our knowledge, only one study has explored this association among Chinese older adults (*4*). Therefore, this study aimed to explore the association between HL and cognitive impairment using a large sample, community-based investigation among elderly people. This study utilized data from the second round of the Prevention and Intervention on Neurodegenerative Disease for Elderly in China (PINDEC) project, which was conducted in Liaoning, Henan, and Guangdong provinces in 2019–2020. A total of 10,347 community-dwelling older adults aged 60 years and above were recruited using a stratified, multi-stage cluster sampling method. After adjusting for confounding factors, the multivariate logistic regression analysis showed that, compared with the no HL group, the odds ratios (*OR*s) for cognitive impairment were 1.23 [95% confidence interval (*CI*): 1.08, 1.40] for mild HL, 1.55 (95% *CI*: 1.32, 1.82) for moderate HL, and 1.87 (95% *CI*: 1.47, 2.39) for severe or profound HL. The association between HL and cognitive impairment highlights the need to integrate the early identification of these problems into primary care, as both are risk factors for healthy aging and potentially preventable and/or treatable conditions.

The PINDEC project was initiated in 2015 to explore the epidemiology of neurodegenerative diseases and other common health problems, and their risk factors, among adults aged 60 years and older in China. The second round of field surveys was conducted from 2019 to 2020 in 12 districts/counties across Liaoning, Henan, and Guangdong provinces. These provinces were selected by considering their geographic location, level of economic development, and degree of aging. A stratified multi-stage cluster sampling method was used to select adults aged 60 years or older who had lived at their residence for more than 6 months in the past year. First, two or three cities in each province were selected by simple random sampling. Second, one county and one district were randomly selected in each city. Third, one township or one street was sampled at each county/district using the proportional to population size (PPS) sampling method. Fourth, cluster sampling was used to select several administrative villages or neighborhood committees in the selected townships/streets, until the survey sample size (1,000 respondents) was met. Trained local health staff conducted interviews and physical examinations with all participants to collect information on demographics, lifestyle, activities of daily living, cognitive function screening, sleep quality, hearing function, and olfactory function.

HL was measured by pure-tone audiometry. Pure-tone audiometry was performed for all individuals in a quiet room in which ambient noise did not exceed 50 dB as measured by a sound level meter. Levels of ambient noise were recorded for each subject in a questionnaire. Each ear was tested separately at 0.5, 1, 2, and 4 kHz to obtain the hearing threshold at each frequency. The average of the hearing thresholds at these four frequencies in the better ear was taken as the pure-tone average (PTA). According to the World Health Organization (WHO) 1997 hearing classification criteria (*5*), a PTA ≤25 dB was considered normal hearing, 26–40 dB was mild HL, 41–60 dB was moderate HL, and ≥61 dB was severe or profound HL. A uniform type of audiometer in accordance with the national standard GB/T 7341.1-2010 was used for all tests and was calibrated prior to testing. The detailed investigation workflow is shown in Supplementary Figure S1 (available at https://weekly.chinacdc.cn/).

Cognitive function was assessed using a Chinese version of the Mini-Mental State Examination (MMSE). Cognitive impairment was defined as an MMSE score of ≤17 for illiterate participants (0 years of education), ≤20 for those with a primary school education (1–6 years of education), and ≤24 for those with a junior high school education and above (≥7 years of education) (*6*).

Ethical approval was granted by the Ethnics Commitee of the National Center for Chronic and Noncommunicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention (approval number 201902). All the participants provided written informed consent prior to the survey.

A total of 12,369 participants were selected, and 12,223 completed the survey, yielding a response rate of 98.8%. After data cleaning, 1,876 participants were excluded due to incomplete sociodemographic data or lacking responses to the hearing function test or cognitive function screening questions. Finally, a total of 10,347 participants were included in this study. Demographic characteristics of the categorical variables were described as percentages in the overall population and subgroups. The chi-square test was used to analyze differences between subgroups, with a *P* of <0.05 considered statistically significant. Multivariable logistic regression was used to examine the association of HL with cognitive impairment. All statistical analyses were performed using SAS software (version 9.4; SAS Institute Inc., Cary, USA).

Of the 10,347 participants in the study sample, 57.2% were female, and 58.6% resided in rural areas (Table 1). The average age was 69.1±6.6 years. In 2019–2020, among older adults aged 60 years and above, the prevalence rates of mild HL, moderate HL, and severe or profound HL were 47.2% (95% *CI*: 46.3%, 48.2%), 18.0% (95% *CI*: 17.3%, 18.8%), and 4.5% (95% *CI*: 4.1%, 4.9%), respectively. The prevalence of moderate or higher grades of HL increased with age, from 12.8% at 60–64 years to 52.4% at 80 years and above. Across subgroups, the study found that the prevalence rates of moderate HL and severe or profound HL were likely higher among those residing in rural areas, those of older age, those with fewer years of education, and those who were widowed. There was no statistically significant difference in the prevalence of mild HL between males and females; however, the prevalence rates of moderate HL and severe or profound HL were higher in males than in females (Table 1). The prevalence of cognitive impairment was 19.1% (95% *CI*: 18.3%, 19.8%) overall and increased gradually with the severity of HL in both males and females (*P*<0.001) (Figure 1). The prevalence of cognitive impairment was 14.3% (95% *CI*: 13.1%, 15.5%) for those with normal hearing function, 18.4% (95% *CI*: 17.3%, 19.5%) for those with mild HL, 25.4% (95% *CI*: 23.4%, 27.4%) for those with moderate HL, and 32.3% (95% *CI*: 28.0%, 36.5%) for those with severe or profound HL. Among those with HL, the prevalence of cognitive impairment was higher in females than in males (Figure 1). After adjusting for confounding factors, multivariate logistic regression analysis showed that, compared with the no HL group, the *OR*s for cognitive impairment were 1.23 (95% *CI*: 1.08, 1.40) for mild HL, 1.55 (95% *CI*: 1.32, 1.82) for moderate HL, and 1.87 (95% *CI*: 1.47, 2.39) for severe or profound HL (Table 2).

DISCUSSION

With a large sample of 10,347 community-dwelling older adults in three provinces, this study identified that the prevalence rates of mild HL, moderate HL, and severe or profound HL were 47.2% (95% *CI*: 46.3%, 48.2%), 18.0% (95% *CI*: 17.3%, 18.8%), and 4.5% (95% *CI*: 4.1%, 4.9%), respectively. The prevalence of cognitive impairment was 19.1% (95% *CI*: 18.3%, 19.8%) overall and increased gradually with the severity of HL. Using normal hearing function as the reference group, the *OR*s for having

TABLE 1. Prevalence of hearing loss among community-dwelling elderly by different characteristics in Liaoning, Henan, and Guangdong provinces in China, 2019–2020.

Characteristics	*n* (%)	Grades of hearing loss, % (95% *CI*)			
		Mild	Moderate	Severe or profound	*P*
Total	10,347 (100.0)	47.2 (46.3, 48.2)	18.0 (17.3, 18.8)	4.5 (4.1, 4.9)	
Sex					<0.001
Male	4,433 (42.8)	48.0 (46.6, 49.5)	21.1 (19.9, 22.3)	5.4 (4.7, 6.0)	
Female	5,914 (57.2)	46.7 (45.4, 47.9)	15.8 (14.8, 16.7)	3.9 (3.4, 4.4)	
P for difference		0.166	<0.001	<0.001	
Age (years old)					<0.001
60–64	3,031 (29.3)	44.4 (42.6, 46.2)	11.0 (9.9, 12.1)	1.8 (1.3, 2.3)	
65–69	3,135 (30.3)	49.8 (48.0, 51.5)	13.6 (12.4, 14.8)	2.6 (2.0, 3.1)	
70–74	2,101 (20.3)	51.2 (49.1, 53.4)	20.5 (18.7, 22.2)	4.4 (3.5, 5.3)	
75–79	1,171 (11.3)	46.5 (43.7, 49.4)	28.9 (26.3, 31.5)	9.0 (7.3, 10.6)	
80 and above	909 (8.8)	39.7 (36.5, 42.9)	37.3 (34.1, 40.4)	15.1 (12.7, 17.4)	
P for trend		<0.001	<0.001	<0.001	
Location					<0.001
Urban	4,287 (41.4)	49.4 (47.9, 50.9)	12.9 (11.9, 13.9)	2.9 (2.4, 3.4)	
Rural	6,060 (58.6)	45.7 (44.4, 46.9)	21.7 (20.6, 22.7)	5.7 (5.1, 6.3)	
P for difference		<0.001	<0.001	<0.001	
Education (years)					<0.001
0	2,707 (26.2)	46 (44.1, 47.8)	22.4 (20.8, 24)	7.3 (6.3, 8.3)	
1–6	3,933 (38.0)	48.9 (47.3, 50.4)	18.2 (17, 19.4)	4.5 (3.9, 5.1)	
7–9	2,558 (24.7)	45.9 (44, 47.8)	15.3 (13.9, 16.7)	2.7 (2.1, 3.3)	
10 and above	1,149 (11.1)	47.7 (44.8, 50.6)	13.3 (11.3, 15.3)	2.1 (1.3, 2.9)	
P for trend		0.048	<0.001	<0.001	
Marital status					<0.001
Non-widowed	8,249 (79.7)	47.4 (46.3, 48.5)	16.8 (16, 17.6)	4.1 (3.7, 4.5)	
Widowed	2,098 (20.3)	46.6 (44.5, 48.8)	23.1 (21.3, 24.9)	6.2 (5.2, 7.3)	
P for difference		0.521	<0.001	<0.001	
Occupation					<0.001
Farmer	6,308 (61.0)	48.3 (47.1, 49.5)	19.2 (18.2, 20.2)	5.4 (4.8, 5.9)	
Worker	2,202 (21.3)	46.0 (43.9, 48.1)	16.9 (15.4, 18.5)	3.3 (2.6, 4.1)	
Non-manual	1,837 (17.8)	45.1 (42.9, 47.4)	15.4 (13.8, 17.1)	3.0 (2.2, 3.8)	
P for difference		0.025	<0.001	<0.001	

Note: Non-manual worker includes teachers, researchers, doctors, office workers, and other occupations apart from farmer and worker.
Abbreviation: *CI*=confidence interval.

cognitive impairment increased gradually with the severity of HL: 1.23 (1.08–1.40) for mild HL, 1.55 (1.32–1.82) for moderate HL, and 1.87 (1.47–2.39) for severe or profound HL. Hearing-related social isolation has been proposed to contribute to the association between HL and poorer cognitive function. The association between HL and cognitive impairment highlights the need to enhance public awareness of hearing protection, and it is crucial to minimize the adverse impact of HL on language and cognitive development.

This study shows that the prevalence of mild HL (47.2%) was higher than that reported in a 2014–2015 survey (34.8%), while the prevalence of moderate or higher grades of HL was 22.5%, slightly lower than that survey (24.1%) (*1*). This study found that the prevalence of moderate or higher grades of HL increased with age, rising from 12.8% at the age of

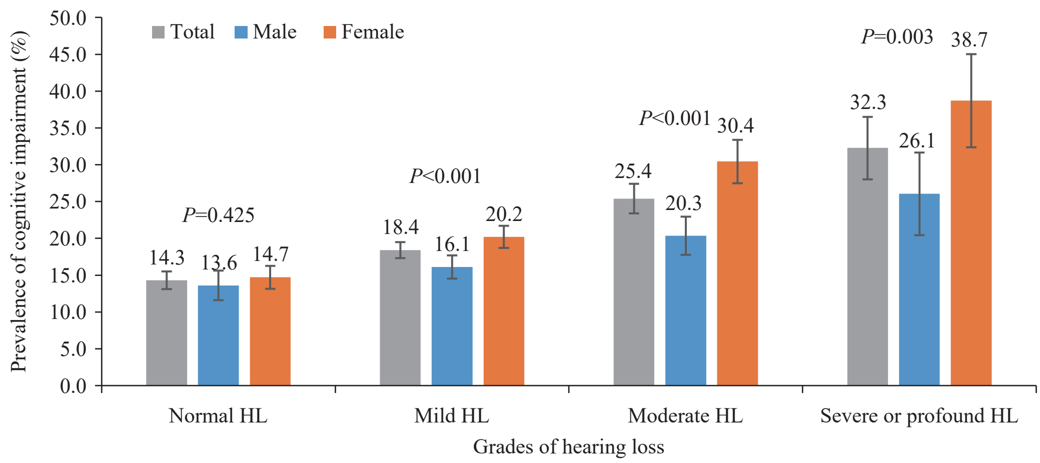

FIGURE 1. Prevalence of cognitive impairment among elderly with different grade of HL by genders in Liaoning, Henan, and Guangdong provinces in China, 2019–2020.
Note: *P* denotes the prevalence difference of cognitive impairment between males and females in each grade of HL among older adults.
Abbreviation: HL=hearing loss.

TABLE 2. Multivariable logistic regression analysis for cognitive impairment among community-dwelling elderly in Liaoning, Henan, and Guangdong provinces in China, 2019–2020.

Subgroups	*OR*	95% *CI*	*P*
Normal HL	1.00		
Mild HL	1.23	1.08–1.40	0.002
Moderate HL	1.55	1.32–1.82	<0.001
Severe or profound HL	1.87	1.47–2.39	<0.001

Note: The multivariable logistic regression had adjusted demographic variables including age, sex, urban-rural status, educational level, occupation and marital status; behavioral variables such as smoking, alcohol drinking, regular tea drinking, regular exercise, living with family, and reading; cardiovascular risk factors such as BMI, hypertension, diabetes, dyslipidemia, heart disease, and cerebrovascular disease.
Abbreviation: HL=hearing loss; *CI*=confidence interval; *OR*=odds ratio; BMI=body mass index.

60–64 years to 52.4% at 80 years and above, consistent with global trends (*7*). Individuals with lower socioeconomic status, such as those living in rural areas, with fewer years of education, or who were widowed, were more likely to have moderate or severe HL. This disparity may reflect limited access to ear and hearing care resources and services among these populations (*7*). Consistent with other studies, we found that HL was associated with cognitive impairment (*3*). More specifically, this study found that any grade of HL was related to cognitive impairment, a finding somewhat different from a previous study that found only individuals with moderate or severe HL performed worse in cognitive assessments (*8*). This discrepancy may be due to differing criteria for HL grades and different cognitive function assessment scales. The association between HL and cognitive impairment remains unclear (*3*). HL may contribute to cognitive decline through impaired speech perception or a broader physiological decline, including vascular decline.

A cohort study suggested that hearing aids might prevent or delay dementia onset and progression (*9*). The WHO recommends hearing screening followed by prompt hearing aid provision for older adults, as this is associated with significant improvements in hearing-related health outcomes. Hearing function should be protected throughout the life course, as many causes of HL can be prevented through public health strategies and clinical interventions (*7*).

This study was subject to some limitations. First, the cross-sectional design precludes inferences about temporal associations between HL and cognitive impairment. Second, data from the three provinces are not nationally representative. Third, the time course of HL could not be determined for inclusion in the regression models, which may be associated with cognitive decline in older adults.

In conclusion, this study found that HL was prevalent among community-dwelling older adults and a possible modifiable risk factor for cognitive impairment. These findings suggest that enhancing public awareness of hearing protection is important for preventing cognitive impairment. Moreover, promoting HL screening and cognitive function assessment during elderly health examinations or primary care management is crucial for healthy aging.

Conflicts of interest: No conflicts of interest.

Acknowledgements: All participants who took part in the project and doctors from collaborative hospitals, on-site work organization of primary medical and public health institution, supervision and guidance by all experts during the project implementation process.

Funding: Supported by Major Public Health Special Project of Ministry of Finance (131091106000150003).

doi: 10.46234/ccdcw2024.177

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Submitted: February 06, 2024; Accepted: May 06, 2024

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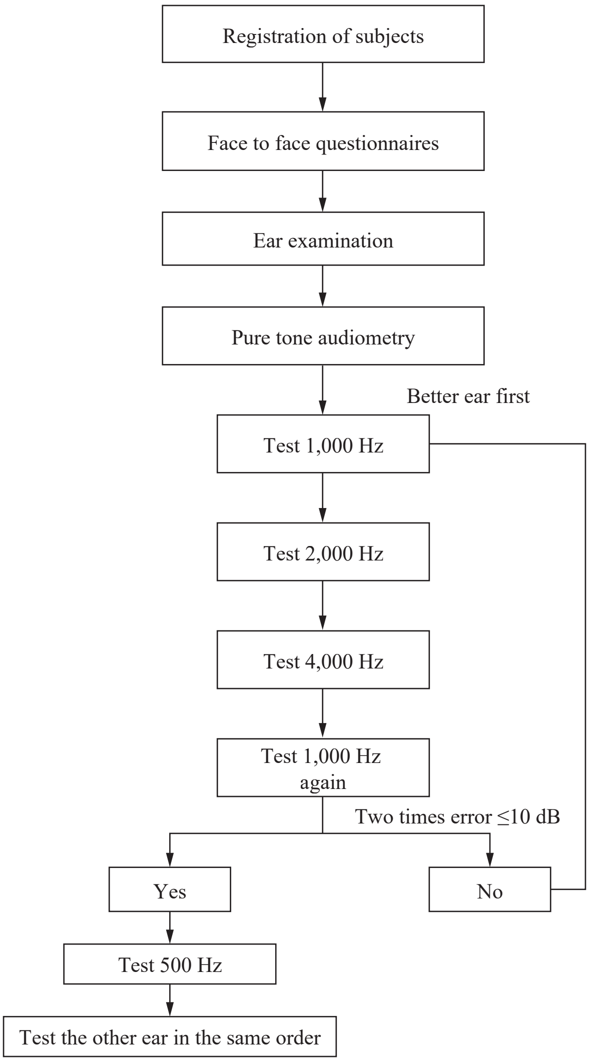
SUPPLEMENTARY MATERIAL



SUPPLEMENTARY FIGURE S1. The workflow of investigation and pure-tone audiometry test.

Preplanned Studies

Handgrip Strength and Low Muscle Strength Rate in Chinese Adults — China, 2020

Jiarong Zhu[1]; Jingjing Wang[1]; Chaoqun Fan[1]; Dongming Wu[1]; Qiang Feng[1,#]

Summary

What is already known on this topic?

Handgrip strength (HS) serves as a diagnostic marker for low muscle strength rate (LMSR) and reflects the level of skeletal muscle. Over the past two decades, global data indicate a downward trend in HS across various countries.

What is added by this report?

According to the latest national data, the mean HS among Chinese adults aged 20 years and older was recorded at 40.4 kg for males and 25.1 kg for females in 2020. A decline in HS was observed with increasing age, particularly among women. Additionally, lower HS values were reported in rural areas, whereas LMSR was more prevalent in these regions.

What are the implications for public health practice?

The analysis of HS and LMSR among Chinese adults is essential for the development and implementation of targeted interventions aimed at improving HS prevalence rates. This analysis is highly significant for public health, contributing to increased public awareness of LMSR and the promotion of preventative measures.

Handgrip strength (HS) significantly influences quality of life and is a critical determinant of overall human health (*1*). Research has established that low HS is linked with heightened risks of all-cause mortality and cardiovascular disease (*2*). This study draws on data from the 2020 Chinese National Survey on Adults' Fitness, the most comprehensive nationally representative survey in China. HS measurements were conducted using the Jianmin II device (Beijing Municipality, China). Findings from 2020 show that the mean HS among Chinese adults was 32.8 kg with a standard deviation of 13.2 kg, representing a decrease of 3.1 kg from 2000 (*3*). Additionally, the low muscle strength rate (LMSR) markedly increases with age; individuals aged 75 to 79 have an LMSR 13.7 times higher than those aged 20 to 24. Investigating the current condition of HS and LMSR among Chinese adults holds significant public health importance, as it aids in devising strategies to prevent or delay the decline in muscle strength, thereby reducing disease burden and enhancing population health.

This study adopted a complex, stratified multistage probability cluster sampling design detailed in previous reports (*4*), with further elaboration provided in Supplementary Material (available at https://weekly.chinacdc.cn/). It then adjusted the 2020 survey data weighting based on gender and age distributions in 5-year increments as per the 7th National Population Census, reported by the National Bureau of Statistics in 2020, covering 31 provincial-level administrative divisions (PLADs). For measuring HS, this study employed a Jianmin II HS measurement device (Beijing, China) to assess the maximal HS in the dominant hand. Prior to testing, participants adjusted the grip width to an appropriate force with their dominant hand, stood upright with feet apart at shoulder width, and arms naturally positioned, inclining 10–30° from the trunk. The maximal HS value was recorded after three consecutive tests (in kg, rounded to the nearest 0.1 kg), ensuring a minimum rest interval of two minutes between tests. Low muscle strength (LMS) was classified following the Asian Working Group for Sarcopenia (AWGS) guidelines, diagnosing males with HS under 26 kg and females under 18 kg as LMS. This study calculated the LMSR for 2020 using a weighted logistic regression model, with diagnostic status as the outcome. The prevalence odds ratio (POR) was determined by gender and by comparing urban versus rural residency, using males and urban residents as reference categories. Two POR models were applied: a crude model leveraging only sampling weights and an adjusted model that included additional covariates such as urban or rural residence, minority status, education level, occupation, economic level by PLADs, along with sampling weights (Supplementary Table S1, available at https://weekly.chinacdc.cn/). Outliers in the HS and weight data that exceeded 1.5 times the interquartile range were excluded as per Tukey's method. In 2020, out of

158,720 potential participants aged 20 to 79 contacted, 128,759 agreed to participate, resulting in a response rate of 81.1%. Non-responders — those who refused to participate, did not respond, were physically or mentally unable to participate, did not reside at their registered address, or provided three or more missing or implausible responses in the questionnaire — were excluded from the analysis (*5*) (Supplementary Figure S1, available at https://weekly.chinacdc.cn/). The name of sampling cities (districts and counties) in Supplementary Table S2 (available athttps://weekly.chinacdc.cn/). The study's protocol involving human participants was ethically approved by the General Administration of the Sports of China, with informed consent obtained from all participants. Kernel density estimation was employed for the density map (Table 1). Statistical significance was set at a two-sided *P* value of less than 0.05. All statistical analyses were conducted using R software (version 4.1.1; R Foundation for Statistical Computing, Vienna, Austria), with results reported as odds ratios (*OR*s) for dichotomous outcomes and associated 95% confidence intervals (*CI*).

TABLE 1. Basic data on handgrip strength and the low muscle strength rate in China, 2020.

Items	Handgrip strength, Mean (SD), kg	Low muscle strength rate, % (95% *CI*)
Total (*n*=128,759)	32.8 (13.2)	9.0 (8.8, 9.1)
Sex		
Male (*n*=64,679)	40.4 (8.7)	8.1 (7.9, 8.3)
Female (*n*=64,080)	25.1 (5.4)	9.1 (8.8, 9.3)
Rural and Urban		
Rural (*n*=68,598)	31.7 (10.6)	11.6 (11.4, 11.9)
Urban (*n*=60,161)	34.0 (10.9)	5.3 (5.1, 5.5)
Age group		
20–24 (*n*=10,159)	35.1 (9.3)	2.7 (2.4, 3.0)
25–29 (*n*=10,738)	35.5 (10.6)	2.9 (2.6, 3.2)
30–34 (*n*=11,016)	35.9 (12.0)	2.5 (2.2, 2.8)
35–39 (*n*=10,599)	35.6 (10.5)	2.5 (2.2, 2.8)
40–44 (*n*=10,740)	35.4 (10.1)	2.9 (2.6, 3.3)
45–49 (*n*=10,779)	34.9 (10.9)	3.0 (2.7, 3.4)
50–54 (*n*=10,186)	33.9 (11.0)	3.8 (3.5, 4.2)
55–59 (*n*=9,696)	33.1 (9.8)	5.0 (4.6, 5.5)
60–64 (*n*=11,426)	29.7 (9.6)	12.8 (12.1, 13.4)
65–69 (*n*=11,476)	28.3 (9.1)	17.2 (16.5, 17.9)
70–74 (*n*=11,258)	26.4 (7.1)	28.7 (27.8, 29.6)
75–79 (*n*=10,686)	24.9 (5.8)	37.1 (36.1, 38.1)

Abbreviation: SD=standard deviation; *CI*=confidence interval.

For HS as shown in Table 1, the average HS in males is significantly higher than in females ($P<0.001$). In 2020, HS in the 20–24 age group was noted to decrease by 10.2 kg, from 35.1 kg to 24.9 kg in those aged 75–79. The peak HS occurs between ages 30–34. Additionally, urban residents have a mean HS that is 2.3 kg greater than that of rural residents ($P<0.001$). Figure 1 depicts the distribution of HS across various demographics. For the LMSR, data presented in Tables 1 and 2 indicate similarities with the HS findings. Using the male LMSR data as a benchmark, the adjusted model reveals that the *OR* for females is 0.96 (95% *CI*: 0.92, 1.00), suggesting that males are more likely to have higher LMSR than females. Among Chinese adults, those in the 75–79 age group exhibit the highest LMSR, being 13.4 times greater than those in the 20–24 age group, according to the adjusted model. Furthermore, there is a pronounced increase in LMSR after the age of 60.

DISCUSSION

Utilizing the latest nationally representative data, this research explored HS levels and LMSR among Chinese adults. The findings revealed that Chinese males exhibited significantly higher HS levels (40.4 kg) compared to Chinese females (25.1 kg). Additionally, a decline in HS was observed at an earlier age among Chinese adults, with the peak HS reached between the ages of 30–34, followed by a gradual decrease with advancing age. Moreover, adults living in urban areas showed higher HS levels and lower LMSR compared to their rural counterparts.

HS varies significantly between China and other countries. In a 2015 prospective urban epidemiological study, HS was assessed among 125,462 adults aged 35–70 years from diverse regions globally. The highest median HS levels were observed in Europe and North America at 30.0 kg (25%–75th percentile: 26.0–35.0 kg) (*6*). In contrast, the average HS in China was reported as 32.8 kg with a standard deviation of 13.2 kg. Furthermore, a Brazilian study indicated that the HS for males and females aged over 20 years was 42.8±0.4 kg and 25.4±0.3 kg, respectively (*7*). Such discrepancies in HS can be attributed to various factors including social and economic conditions, environmental influences, methods of HS measurement, sampling conditions, and behavioral habits. Therefore, regional HS assessments should be considered as primarily reference values. Trends in HS levels across different regions suggest significant

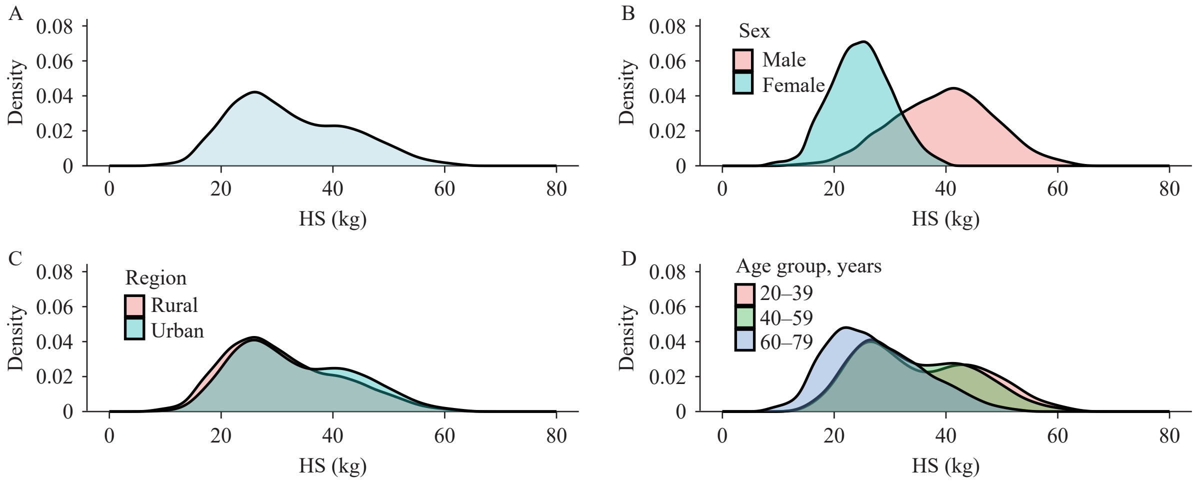


FIGURE 1. Handgrip strength distributions across various groups in China, 2020.
(A) Handgrip strength distribution; (B) Handgrip strength distribution of different sex; (C)Handgrip strength distribution between rural and urban areas; (D) Handgrip strength distribution between different age groups.

TABLE 2. Analysis of the POR of low muscle strength rate among various groups of Chinese adults in 2020.

Items	Crude model POR (95% *CI*)	Adjusted model POR (95% *CI*)
Sex		
Male (*n*=64, 679)	Ref.	Ref.
Female (*n*=64, 080)	1.13 (1.09, 1.17)	0.96 (0.92, 1.00)
Rural and urban		
Rural (*n*=68, 598)	Ref.	Ref.
Urban (*n*=60, 161)	2.35 (2.25, 2.45)	1.16 (1.10, 1.22)
Age, years		
20–24 (*n*=10, 159)	Ref.	Ref.
25–29 (*n*=10, 738)	1.08 (0.91, 1.28)	1.11 (0.93, 1.32)
30–34 (*n*=11, 016)	0.93 (0.78, 1.11)	0.96 (0.81, 1.15)
35–39 (*n*=10, 599)	0.92 (0.77, 1.10)	0.94 (0.79, 1.13)
40–44 (*n*=10, 740)	1.10 (0.92, 1.30)	1.06 (0.89, 1.26)
45–49 (*n*=10, 779)	1.13 (0.95, 1.34)	1.05 (0.89, 1.26)
50–54 (*n*=10, 186)	1.44 (1.23, 1.70)	1.34 (1.13, 1.58)
55–59 (*n*=9, 696)	1.93 (1.65, 2.26)	1.80 (1.53, 2. 12)
60–64 (*n*=11, 426)	5.33 (4.65, 6.12)	4.91 (4.23, 5.23)
65–69 (*n*=11, 476)	7.55 (6.59, 8.65)	6.65 (5.73, 7.72)
70–74 (*n*=11, 258)	14.61 (12.79, 16.70)	12.62 (10.90, 14.63)
75–79 (*n*=10, 686)	21.42 (18.75, 24.47)	18.44 (15.91, 21.37)

Note: Crude model: only sampling weights are considered; adjusted model: based on the sample population, urban and rural areas, ethnic groups, occupations, educational levels, economic conditions in the PLADs.
Abbreviation: *CI*=confidence interval; POR=prevalence odds ratio; PLAD=provincial-level administrative division; Ref.=reference group.

changes. From 2000 to 2017, data revealed a declining trend in several countries: China showed a percent decrease per decade of −4.0 (95% *CI*: −4.3, −3.7), Japan −0.6 (−0.9, −0.3), England −6.3 (−7.2, −5.4), Western Europe −2.3 (−3.0, −1.6), Canada −4.7 (−5.3, −4.1), and the USA −1.5 (−2.3, −0.7). Conversely, Northern Europe and Southern Europe exhibited growing trends at rates of 3.3 (2.8, 3.8) and 7.0 (6.1, 7.9), respectively (*8*). Despite improvements in quality of life, health status as measured by HS is not improving in most regions. Predominantly, HS research has been concentrated in high-income countries, with a paucity of data from low and middle-income nations. Future studies should focus on contemporary HS levels, and explore interventions and cohort studies to enhance HS. Resistance training and scientifically informed nutritional intake have been demonstrated to effectively boost HS and muscle mass. Important nutritional factors include protein, vitamin D, omega-3 fatty acids, magnesium, adherence to a Mediterranean diet, and increased consumption of fruits and vegetables (*9*–*10*). It is advisable for China to promote resistance training and these nutritional practices, especially among women, to improve HS.

Exercise remains the cornerstone of sarcopenia management. The study indicated an age-related escalation in the LMSR among Chinese adults. Specifically, the LMSR in individuals aged 55–59 was approximately 7.4 times higher than in those aged 75–79. Additionally, females demonstrated a significantly higher risk than males. *The European Working Group on Sarcopenia in Older People* has previously highlighted the prevalence of sarcopenia in the elderly, noting its strong correlation with both disability and mortality (*11*). Thus, it is vital to focus on enhancing muscle mass and strength, especially in older women, to improve their quality of life.

HS often manifests as an external indicator of various skeletal muscle system diseases (*12*). HS is recognized as an indicator of healthy aging (*13*). Research has shown that HS has a stronger association with overall mortality and cardiovascular disease mortality than either systolic blood pressure or total physical activity levels (*2*). Musculoskeletal disorders are increasingly recognized as major public health challenges, impacting the burden of disease and overall health status. According to the World Health Organization (WHO) in 2019, the disability-adjusted life years (DALYs) attributable to musculoskeletal disorders saw a 65.74% increase from 1990 to 2017, highlighting its significance as a global health issue (*14*). Consequently, it is essential to explore preventative strategies against muscle weakness in adults, underlining the need for extensive research on muscle strength.

The strength of this study is derived from its use of contemporary data collected from all 31 PLADs, municipalities, and districts across China, which enhances its credibility.

However, it does present certain limitations that warrant attention. First, this study is a cross-sectional study, so we cannot explain causal relationship. Then, we collected covariates using a self-reported questionnaire, which might have led to recall bias. Specifically, the classification of LMSR is overly simplistic and would benefit from a more nuanced categorization into mild, moderate, and severe levels to facilitate more effective intervention strategies.

In conclusion, this study provides an up-to-date assessment of the prevalence of HS and LMSR across China as of 2020, on a national and population-based scale. Consequently, it is recommended that further policies be developed to improve HS and skeletal muscle levels among women, the elderly, and rural communities.

Conflicts of interest: No conflicts of interest.

doi: 10.46234/ccdcw2024.178

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Submitted: February 06, 2024; Accepted: July 01, 2024

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SUPPLEMENTARY MATERIAL

Handgrip Strength (HS) and Weight Measurement

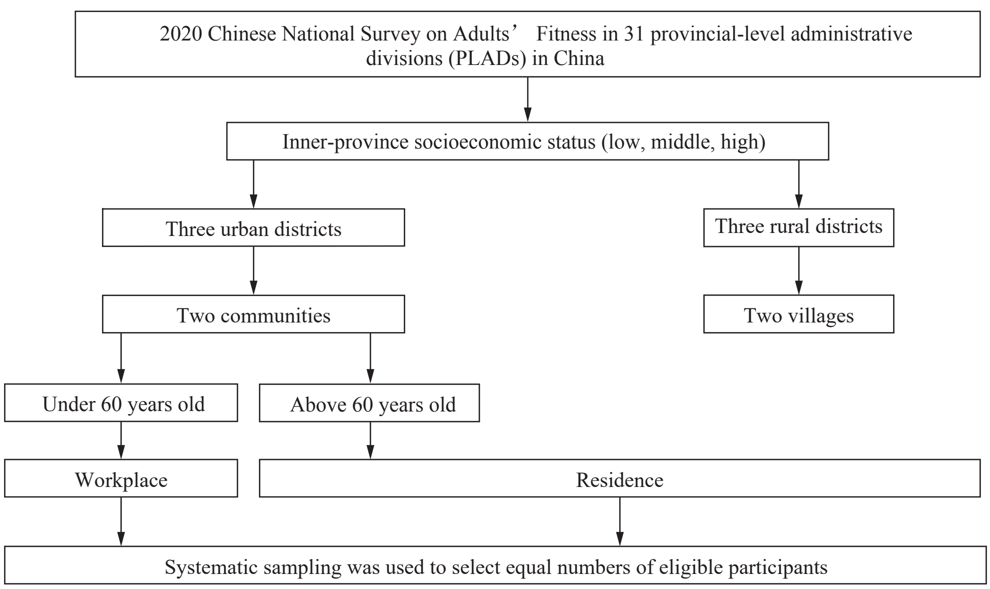
We used a handgrip strength measurement device (Jianmin II, Beijing Municipality, China) to measure the HS in the dominant hand. Before the measurement, the participants held the grip handles with their dominant hand and adjusted the grip width by applying an appropriate grip force. Participants remained upright, with feet naturally separated at shoulder width and arms dropped naturally and inclined at a 10–30° angle from the trunk. After three consecutive tests, we recorded the maximal value for each participant (HS in kg, rounded up to 0.1 kg) with adequate rest intervals (2 min or longer)(*1*).

Study Design and Participants

Using a complex stratified multistage probability cluster sampling design, we analyzed data from the 2020 Chinese National Survey on Adults' Fitness, the largest nationally representative survey of civilians in China, which was conducted from August to November 2020. The details of recruitment have been described elsewhere (*2*).

Briefly, 31 provincial-level administrative divisions (PLADs) were covered in the first stage. In the second stage, three sub-provincial or prefectural-level cities ranked between PLADs and counties in the administrative structure of China were randomly selected from each province, based on their economic positions weighted by the gross domestic product assessment, which constitutes the inner-provincial socioeconomic status (low, middle, and high). Three urban districts (or three rural counties) in each city were selected in the third stage. Three city streets (or rural towns) were chosen for the fourth stage. Two-street community societies (or villages) were selected for the fifth stage. In the final stage, systematic sampling was used to select equal numbers of eligible participants from each workplace or residence to be followed up for at least 3 years. The retirement age in China is 60 years. Participants who were younger than 60 years and living in cities were chosen from the sampling sites based on their workplaces, and participants older than 60 years and living in rural areas were chosen from the sampling sites based on their home addresses. All participants were chosen on the basis of the principles described above and represented Chinese people living in rural and urban areas (Supplementary Figure S1).

After receiving explanations from trained investigators, participants completed a questionnaire to provide information about demographic characteristics (sex, age, nationality, education level, and career). Each participant signed an informed consent form prior to enrolment. The study protocol was approved by The General Administration of Sport of the People's Republic of China (*3*).



SUPPLEMENTARY FIGURE S1. Flow chart of sampling design in the 2020 Chinese National Survey on Adults' Fitness.

SUPPLEMENTARY TABLE S1. Information of covariates.

Covariate group	*n*
Inner-provincial socioeconomic status	
High	42,104
Middle	43,294
Low	41,536
Education level	
Primary school or lower	32,034
Junior high school	28,051
Senior high school	22,406
University and above	44,791
Career	
Technical staff	46,809
Business people	8,595
Agricultural personnel	36,359
Other occupations	35,336
Nationality	
Han	113,221
Minority	16,538

SUPPLEMENTARY TABLE S2. Name of sampling cities (districts and counties) of PLADs.

Code	PLADs	First class cities (districts, counties)	Second class cities (districts, counties)	Third class cities (districts, counties)
11	Beijing	Haidian, Fangshan	Chaoyang, Miyun	Fengtai, Yanqing
12	Tianjin	Hepin, Beichen	Hexi, Jinnan	Nankai, Jinghai
13	Hebei	Shijiazhuang	Cangzhou	Chengde
14	Shanxi	Taiyuan	Datong	Yuncheng
15	Nei Monggol	Hohehot	Chifeng	Bayannur
21	Liaoning	Shenyang	Dandong	Chaoyang
22	Jilin	Changchun	Jilin	Yanbian
23	Heilongjiang	Harbin	Shuangyashan	Suihua
31	Shanghai	Xuhui, Songjiang	Jiading, Pudong	Yangpu, Fengxian
32	Jiangsu	Nanjing	Wuxi	Xuzhou
33	Zhejiang	Hangzhou	Wenzhou	Jiaxing
34	Anhui	Hefei	Fuyang	Huangshan
35	Fujian	Fuzhou	Xiamen	Sanming
36	Jiangxi	Nanchang	Shangrao	Ganzhou
37	Shandong	Jinan	Yantai	Binzhou
41	Henan	Zheng zhou	Sanmenxia	Shangqiu
42	Hubei	Wuhan	Huanggang	Shiyan
43	Hunan	Changsha	Zhuzhou	Zhangjiajie
44	Guangdong	Guangzhou	Zhanjiang	Shaoguan
45	Guangxi	Nanning	Guilin	Yulin
46	Hainan	Sanya	Qionghai	Danzhou, Ledong
50	Chongqing	Yuzhong, Yongchuan	Nanan, Fengdu	Jiulongpo, Qianjiang

Continued

Code	PLADs	First class cities (districts, counties)	Second class cities (districts, counties)	Third class cities (districts, counties)
51	Sichuan	Chengdu	Zigong	Guangyuan
52	Guizhou	Guiyang	Liupanshui	Qiannanzhou
53	Yunnan	Kunming	Puer	Lincang
54	Xizang	Lhasa	Nyingchi	Nagqu
61	Shaanxi	Xi'an	Yan'an	Ankang
62	Gansu	Lanzhou	Tensui	Wuwei
63	Qinghai	Xining	Haixi	Guoluozhou, Xunhuazhou
64	Ningxia	Yinchuan	Shizuishan, Wu Zhong	Guyuan
65	Xinjiang	Urumqi	Kashgar	Altay

Abbreviation: PLAD=provincial-level administrative division.

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Indexed by Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), PubMed Central (PMC), Scopus, Chinese Scientific and Technical Papers and Citations, and Chinese Science Citation Database (CSCD)

The inauguration of *China CDC Weekly* is in part supported by Project for Enhancing International Impact of China STM Journals Category D (PIIJ2-D-04-(2018)) of China Association for Science and Technology (CAST).

CCDC weekly

Vol. 6 No. 32 Aug. 9, 2024

Responsible Authority
National Disease Control and Prevention Administration

Sponsor
Chinese Center for Disease Control and Prevention

Editing and Publishing
China CDC Weekly Editorial Office
No.155 Changbai Road, Changping District, Beijing, China
Tel: 86-10-63150501, 63150701
Email: weekly@chinacdc.cn

CSSN
ISSN 2096-7071 (Print)
ISSN 2096-3101 (Online)
CN 10-1629/R1