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RESEARCH

Profile of non-invasive physical health indicators associated with cognitive performance in Chinese older adults: evidence from the China Health and Retirement Longitudinal Study

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Abstract

Background Existing studies have indicated the potential role of non-invasive physical health indicators as an early detector of mild cognitive impairment (MCI) in older adults. However, evidence is lacking in determining the appropriate physical health indicators for early screening of cognitive decline in each domain. Therefore, the current study aimed to establish a comprehensive physical health indicators profile in association with cognitive performance.

Methods The present study utilized a three-year longitudinal cohort design, with data from the China Health and Retirement Longitudinal Study (CHARLS). 4,869 participants aged 60–97 years from CHARLS wave 2015 and 2018 who were cognitively and physically healthy were included in analysis. Physical functions (BMI, grip strength, blood pressure, balance tests, course walking time, repeated chair stands, and pulmonary function) were objectively measured by physical tasks. Cognitive performance domains (general cognition, episodic memory, executive function, verbal fluency, orientation, and language-and-praxis) were measured through standardised interviews and cognitive tasks. Multiple linear regression models were conducted to explore the association between physical health indicators and cognitive performance. Subgroup analysis was conducted to identify sex-specific factors.

Results Pulmonary function was identified as associated with all domains of cognitive performance in older adults (β ranged between 0.05 and 0.08). Right grip strength was also identified as an important factor associated with all

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cognitive domains except general cognition (β ranged between 0.04 and 0.12). Subgroup analysis revealed that the association between physical health indicators and cognitive performance is more pronounced in males than in females.

Conclusions A profile of non-invasive physical health indicators associated with cognitive performance was established, which warrants future incorporation of non-invasive physical health indicators in early risk screening systems for MCI, enabling timely intervention and prevention in older adults. Future studies can delve deeper into the mechanisms underlying this full-dimensional relationship between physical and cognitive domains.

Keywords Mild cognitive impairment, Screening, Cognition, Memory

Background

Population aging has become a pressing global issue in recent decades [1, 2], elevating the population risk of aging-related health concerns. Mild cognitive impairment is particularly burdensome among the older adult population [3], with prevalence rising with age and risk factors varying across different demographics such as age and sex [4]. In China, where population aging is a fundamental national concern [5], the reported incidence of mild cognitive impairment is 15.4% [6], which severely impacts quality of life and social function of the older adult population [7]. The high prevalence of mild cognitive impairment highlights the importance of early screening and identification of at-risk individuals to enable timely intervention and prevention.

Current risk assessment of mild cognitive impairment predominantly relies on cognitive assessment and neuroimaging [8, 9], which are constrained by the high training requirements, resource demands and under-supported measurement consistency [10]. Moreover, these assessments often require a certain level of literacy, as the instructions can be hard to follow for individuals without adequate education background, while the education level of older people in developing countries including China is relatively low [11]. Therefore, there is a pressing need for more affordable, accessible, and efficient early screening methods for mild cognitive impairment.

Non-invasive physical health indicators have emerged as potential screening factors, which can be measured through routine physical examinations. Cross-sectional studies have demonstrated significant associations between cognitive performance and a set of non-invasive physical health indicators, including grip strength, blood pressure, balance, course walking time, and repeated chair stands [12–16]. Moreover, preliminary longitudinal evidence has indicated that early and middle-age physical health indicators are longitudinally associated with poorer cognitive performance and a higher risk of dementia at an older age. For example, higher body mass index (BMI) was associated with worse verbal fluency and episodic memory, while poor pulmonary function was associated with worse memory, visuospatial ability, processing speed, and verbal fluency [17, 18]. These physical indicators could serve as viable options for early screening of mild cognitive impairment in older adults.

Nevertheless, several obstacles remain for leveraging non-invasive physical health indicators as factors for early screening of mild cognitive impairment. Firstly, current investigations into the associations between non-invasive physical health indicators and mild cognitive impairment are limited to establishing isolated associations between specific non-invasive physical health indicators and cognitive domains. For example, the association between poor pulmonary function and worse episodic memory [17, 19], as well as between greater grip strength and better episodic memory [20]. However, there is a lack of a comprehensive investigation to identify whether non-invasive physical health indicators are prospectively associated with the decline across the spectrum of cognitive abilities. Another issue is that primary indicators of people's physical health are integral and might interact with each other [21, 22]. This inter-correlation raises the possibility of overestimating the effect of a single physical health indicator on cognitive performance if the influence of other physical indicators is ignored. Moreover, it remains unexplored whether there exists a key factor that has full-dimensional association with cognitive performance which could facilitate more efficient screening. Considering the quality of evidence, despite the acknowledged advantage of longitudinal over cross-sectional data in facilitating causal inference [23], there still lacks longitudinal studies to investigate the temporal relationship between most physical health indicators and cognitive performance, such that the physical health indicators should be measured before the cognitive performance to reduce the risk of reverse causality for a potential causal relationship to be established. This lack of longitudinal evidence also restrained the use of physical health indicators as early screening factors for mild cognitive impairment. Addressing these gaps is crucial for establishing robust early screening methods for mild cognitive impairment based on non-invasive physical health indicators.

To address the obstacles, the present study aimed to establish a comprehensive profile of non-invasive physical health indicators in association with the subsequent spectrum of cognitive performance in Chinese older adults through a longitudinal design. We also explored whether physical health indicators have age- and sex-specific associations with cognitive performance. This approach seeks to provide a foundation for future early detection of cognitive deterioration based on non-invasive physical health indicators in older adults.

Methods

Study design and population

The sample was drawn from the China Health and Retirement Longitudinal Study (CHARLS) [24], which is an ongoing national representative longitudinal study of over 17,000 middle-aged and older adults (aged 45–97 years) from 450 resident communities and villages across 28 provinces in China. The baseline survey was carried out between June 2011 and March 2012, followed by 4 waves in 2013, 2015, 2018 and 2020, with information collected using face-to-face computer-assisted personal interviews.

Participants who were over 60 years old who participated in physical health measurements without physical disabilities, brain damage, cognitive retardation, or memory-related disease (such as dementia, brain atrophy, and Parkinson's disease) entered in 2015 and 2018 were included in this study. We utilized data on physical health indicators collected in 2015, and data on cognitive performance collected in 2015 and 2018. Demographic characteristics including age (years), sex (male/female), and education (illiterate/primary school/middle school and above) were self-reported in 2018. Participants without complete data on demographic information were removed.

A total of 4,869 participants met the requirements for inclusion and exclusion criteria, making them eligible for the primary analyses (ages ranging from 60 to 97 years). Supplementary Figure S1 shows the process of participant inclusion. The institutional review board at Peking University granted the CHARLS ethical approval. Written informed consent was given by each participant who agreed to take part in the study. The study adhered to the guidelines of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).

Measurement of cognitive performance

Cognitive performance was measured by CHARLS wave 4 (year 2018) standardized cognitive tests and interview questions. Six domains of cognitive performance were captured, including general cognition, episodic memory, executive function, verbal fluency, orientation, and language-and-praxis. Episodic memory, executive function, and orientation were also measured at wave 3 (year 2015). More information regarding the selection and measurements of cognitive domains in the CHARLS dataset can be found in the study based on the Health and Retirement Study [25]. Please refer to Table S1 in the Supplementary material for detailed instructions and items utilized for each cognitive function measurement.

General cognition was measured by items drawn from the Telephone Interview for Cognitive Status [26] and the Community Screening Instrument for Dementia [27]. A total of eight items were included in the measurement, each item was scored as one if successfully completing the instructions or answering the questions. A total score was calculated by combining the eight items, with a range of 0–8 points. Higher scores indicate better general cognition.

Episodic memory was measured by three components including Word Recall (WR), Delayed Recall (DR), and Wordlist Recognition (WRE) from the Wordlist memory (WLM) tests paradigm [28, 29]. The participants were first shown a list of 10 words by the interviewer. Then participants were asked to recall the words they saw right after the interviewer finishing the list (WR). The participants were introduced to the same word list in different orders three times and were asked to recall the list three times. The score of WR was calculated as the mean number of correctly recalled words, ranged between 0 and 10. After the WR test, participants continued to participate in three measurement scales, followed by a question requesting them to recall the words in the earlier word list again (DR). The score of DR was measured as the number of correctly recalled words, ranged between 0 and 10. Then the participants continued to participate in a set of Number Series task, after which the participants were presented with 20 word-cards. The participants were asked whether they have seen the words before (WRE). The score of WRE was measured as the number of correctly recognised words, ranged between 0 and 10. The total score was calculated through adding the scores of each component, with a range of 0–30 points. Higher scores indicate better episodic memory.

Executive function was measured by the Number Series tasks adapted from a patterning assessment paradigm, in which participants were shown as series of numbers [30]. Each series of numbers contained a blank part. The participants were asked to identify the patterns of the numbers and fill in the blank. A total of 15 number series were presented. Success in each task was scored as one. The total score ranged between 0 and 15 points, with higher scores indicating better executive function.

Verbal fluency was evaluated by the Retrieval Fluency task, in which the participants were asked to recall as many animal names as they could in 60 s [31, 32]. The score was measured as the number of unique animal names recalled, with higher scores indicating better verbal fluency.

Orientation was measured by items from the Mini Mental State Exam (MMSE) [33]. A total of 10 items asking participants about basic information of the current time and situation were utilized. Correct answer to each item was scored as one. The Total score ranged between 0 and 10 points, with higher scores indicating better orientation.

Language-and-praxis was also evaluated by items from MMSE [33]. A total of seven items were utilized. The first two items required participants to view a picture and name its contents. Each correct answer was scored as one. The third item involved asking the participants to repeat a short phrase from the interviewer. Successful completion was scored as one. The items 4–7 asked the participants to follow a total of seven instructions. Completion of each instruction was scored as one, forming a score of 0–7. The total scores ranged between 0 and 9 points, with higher scores indicating better language-and-praxis.

Measurement of non-invasive physical health indicators

Physical health indicators were measured by the CHARLS wave 3 (year 2015) physical function questionnaire. Seven types of non-invasive physical health indicators were captured, including BMI, grip strength, blood pressure, balance tests, course walking time, repeated chair stands, and pulmonary function. More information regarding the measurements of physical health indicators can be found in the CHARLS data profile [24].

BMI was calculated using weight in kilograms divided by standing height in meters squared. Higher score indicates higher BMI.

Grip strength was separately measured from right and left hands by a dynamometer. Participants were instructed to stand and hold the dynamometer at a right angle and squeeze the handle for a few seconds. Higher score indicates stronger grip strength.

Blood pressure was evaluated by systolic pressure, diastolic pressure, and pulse using Omron HEM-7200 Monitor. Higher score indicates higher blood pressure.

Balance tests were conducted by the full tandem standing position test, in which, participants were instructed to stand with the heel of one foot in front of and touching the toes of the other foot for about either 30–60 s. Participants could use their arms, bend their knees, or move their body to maintain balance. Whether the participants could successfully complete the position were recorded.

Course walking time was assessed by having participants walking along a 2.5 m course comfortably for two times. The interviewers recorded the time taken (seconds) for completing the course.

Repeated chair stands were commonly used to measure the lower limb strength. Participants were required to stand up straight and then sit down again at the fastest pace five times while keeping their arms folded across their chest. The interviewers recorded the time taken (seconds) for completing the movements. Faster completion time was used as indicator of better lower limb strength.

Pulmonary function was measured by the time taken for participants to expel air from their lungs, which reflects pulmonary ventilation function. Participants were required to stand up, take a deep breath, then blow into the mouthpiece. The interviewers recorded the reading by peak flow meter. Higher scores indicate better pulmonary function.

Please refer to Table S1 in the Supplementary material for more information about the physical health indicators' measurements.

Statistical analysis

Data were analysed in May 2024. To address missing data, multiple imputation through the predictive mean matching method was employed using the "mice" package in R 4.3.3 [34]. We used the independent t-test for continuous variables and chi-squared test for categorical variables to investigate cross-sex differences in non-invasive physical health indicators, cognitive performance, and demographic variables. Multiple linear regression models were applied to determine the associations between physical health indicators and cognitive performance (general cognition, episodic memory, executive function, verbal fluency, orientation, and language-and-praxis), adjusting for age, sex, and education. Sensitivity analysis regarding grip strengths was conducted to compare between the association of grip strengths in right-hand-dominant and left-hand-dominant participants with cognitive performance. Sensitivity analysis was further conducted to explore the associations of physical health indicators with episodic memory, executive functioning, and orientation accounting for baseline scores of these three cognitive functions through generalised estimating equation (GEE) models. Outcomes in 2018 were re-calculated using the same items available in 2015 to ensure meaningful comparisons. Subgroup analyses were conducted to evaluate the differences of the associations identified above between sexes. All cognitive performance outcomes and physical health indicators were standardised for multiple linear regression and GEE models to ensure comparability. The false discovery rate (FDR) correction was applied to address the potential risk of false positives generated from multiple comparisons [35].

Results

Descriptive results

A total of 4,869 individuals were involved in the analysis, including 2,481 (50.96%) females and 2,388 (49.04%) males. The characteristics of the eligible participants are presented in Table 1. The average age of participants in 2018 was 67.26 (SD = 6.20) years. The mean age of females and males was 67.03 (SD = 6.17) years and 67.51 (SD = 6.22) years, respectively. 55.3% of the participants were illiterate or had only elementary school education or lower (n = 4,639). Males were more likely to report receiving higher education compared to females ($p < 0.001$). More males (10.2%; n = 244) completed university-level education compared to females (3.7%; n = 92).

For physical health indicators, the scores of BMI ($p < 0.001$), pulse ($p < 0.001$), course walking time ($p = 0.017$), and repeated chair stands ($p < 0.001$) of females were significantly higher than males, while males had significantly higher scores of right grip strength ($p < 0.001$), left grip strength ($p < 0.001$), systolic ($p < 0.001$), diastolic ($p < 0.001$), full tandem ($p < 0.001$), and pulmonary function ($p < 0.001$) than females. Regarding cognitive performance, males performed better than females in all cognitive domains ($p < 0.001$).

Association between non-invasive physical health indicators and cognitive performance

The association of non-invasive physical health indicators with cognitive performance after controlling for explanatory and confounding variables are presented in Table 2. The results indicated that pulmonary function was significantly associated with all domains of cognitive performance, including general cognition (β = 0.08, $p < 0.001$), episodic memory (β = 0.05, $p < 0.001$), executive function (β = 0.06, $p < 0.001$), verbal fluency (β = 0.07, $p < 0.001$), orientation (β = 0.04, $p = 0.001$), and language-and-praxis (β = 0.08, $p = 0.001$). Right grip strength was also identified as an important factor which was significantly associated with most domains of cognitive functions, including episodic memory (β = 0.04, $p = 0.042$), executive function (β = 0.06, $p = 0.004$), verbal fluency (β = 0.12, $p < 0.001$), orientation (β = 0.07, $p = 0.009$), and language-and-praxis (β = 0.07, $p = 0.037$).

Other physical health indicators were also identified as significantly associated with specific domains of cognitive performance. BMI was positively associated with general

Table 1 Descriptive statistics for eligible participants

Characteristics *	Overall (n = 4869)	Female (n = 2481)	Male (n = 2388)	Between-sex difference (p-value)
Demographics				
Age	67.26 (6.20)	67.03 (6.17)	67.51(6.22)	0.007
Education				< 0.001
Illiterate	1518 (31.2%)	1185 (47.8%)	333 (13.9%)	
Elementary school or lower	3221 (47.9%)	1000 (40.4%)	1331 (55.7%)	
Middle school	684 (14.0%)	204 (8.2%)	480 (20.1%)	
Academic or vocational high school	275 (5.6%)	78 (3.1%)	196 (8.1%)	
Associate degree or higher	61 (1.3%)	13 (0.5%)	48 (2.1%)	
Non-invasive physical health indicators				
BMI (kg/m^2)	23.10 (4.09)	23.94 (4.34)	22.92 (3.75)	< 0.001
Right grip strength (kg)	27.37 (9.62)	21.63 (6.85)	33.35 (8.37)	< 0.001
Left grip strength (kg)	26.06 (9.78)	20.49 (6.49)	31.84 (9.26)	< 0.001
Systolic BP (mmHg)	131.17 (20.22)	131.48 (20.61)	130.84 (19.80)	0.268
Diastolic BP (mmHg)	74.43 (11.13)	73.79 (11.02)	75.10 (11.21)	< 0.001
Pulse (P)	73.52 (10.77)	74.31 (10.18)	72.69 (11.30)	< 0.001
Full tandem				< 0.001
Yes	3851 (79.1%)	1788 (72.1%)	2063 (86.4%)	
No	1018 (20.9%)	693(27.9%)	325 (13.6%)	
Course walking time (Sec)	3.51 (6.45)	3.72 (6.78)	3.28 (6.08)	0.017
Repeated chair stands time (Sec)	9.70 (3.76)	10.19 (4.05)	9.20 (3.38)	< 0.001
Pulmonary function (L/min)	269.86 (111.55)	225.86 (80.63)	315.59 (120.49)	< 0.001
Cognitive performance†				
General cognition (range 0–8)	5.73 (1.52)	5.58 (1.64)	5.89 (1.36)	< 0.001
Episodic memory (range 0–30)	15.00 (5.56)	14.09 (5.63)	15.94 (5.32)	< 0.001
Executive function (range 0–15)	2.99 (2.56)	2.37 (2.54)	3.63 (2.43)	< 0.001
Verbal fluency (range 0-unlimited)	11.28 (4.84)	10.63 (4.72)	12.03 (4.92)	< 0.001
Orientation (range 0–10)	8.19 (2.03)	7.64 (2.31)	8.76 (1.46)	< 0.001
Language-and-praxis (range 0–9)	6.44 (2.05)	6.13 (2.29)	6.86 (1.72)	< 0.001

Note * Mean and (SD) were reported for continuous variables, count and (percentage) were reported for categorical variables. † Measurement score ranges were reported for each cognitive measurement. BMI = Body mass index; BP = Blood pressure

Table 2 Multiple linear regression models of non-invasive physical health indicators predicting cognitive performance

Cognitive performance	Physical health indicators	β	SE	t-value	*p*-value	R^2
General Cognition	BMI	0.04	0.02	2.48	0.020*	0.083
	Right grip strength	0.03	0.02	1.09	0.274	
	Left grip strength	0.03	0.02	1.06	0.465	
	Systolic BP	0.05	0.02	2.35	0.057	
	Diastolic BP	-0.02 [a]	0.02	-0.89	0.651	
	Pulse	-0.03 [a]	0.02	-1.91	0.124	
	Full tandem	-0.03 [a]	0.02	-2.10	0.072	
	Course walking time	0.01	0.01	0.45	0.931	
	Repeated chair stands time	0.00	0.02	0.14	0.886	
	Pulmonary function	0.08	0.02	4.51	< 0.001***	
Episodic Memory	BMI	0.03	0.01	2.62	0.018*	0.302
	Right grip strength	0.04	0.02	2.11	0.042*	
	Left grip strength	0.04	0.02	1.86	0.378	
	Systolic BP	-0.00 [a]	0.02	-0.27	0.790	
	Diastolic BP	-0.01 [a]	0.02	-0.78	0. 651	
	Pulse	-0.00 [a]	0.01	-0.39	0.697	
	Full tandem	0.03	0.01	2.64	0.025*	
	Course walking time	-0.00 [a]	0.01	-0.08	0.934	
	Repeated chair stands time	-0.04 [a]	0.01	-3.49	0.003**	
	Pulmonary function	0.05	0.01	3.33	0.001**	
Executive Function	BMI	0.05	0.01	3.46	0.002**	0.305
	Right grip strength	0.06	0.02	3.24	0.004**	
	Left grip strength	0.03	0.02	1.02	0.465	
	Systolic BP	-0.05 [a]	0.02	-3.20	0.003**	
	Diastolic BP	0.02	0.02	1.56	0.651	
	Pulse	-0.01 [a]	0.01	-1.87	0.124	
	Full tandem	0.02	0.01	2.80	0.025	
	Course walking time	-0.01	0.01	0.45	0.931	
	Repeated chair stands time	-0.04[a]	0.01	-2.92	0.002**	
	Pulmonary function	0.05	0.01	3.80	< 0.001***	
Verbal Fluency	BMI	0.02	0.01	1.62	0.126	0.154
	Right grip strength	0.12	0.03	4.51	< 0.001***	
	Left grip strength	-0.03 [a]	0.02	-1.32	0.465	
	Systolic BP	-0.04 [a]	0.02	-1.90	0.117	
	Diastolic BP	-0.01 [a]	0.02	-0.43	0.695	
	Pulse	-0.03 [a]	0.01	-2.22	0.124	
	Full tandem	0.02	0.01	1.63	0.157	
	Course walking time	-0.00 [a]	0.01	-0.28	0.931	
	Repeated chair stands time	-0.05 [a]	0.02	-3.10	0.004**	
	Pulmonary function	0.07	0.02	4.26	< 0.001***	
Orientation	BMI	0.06	0.02	3.78	0.001**	0.210
	Right grip strength	0.07	0.02	2.85	0.009**	
	Left grip strength	0.01	0.02	0.63	0.587	
	Systolic BP	-0.02 [a]	0.02	-0.86	0.391	
	Diastolic BP	-0.02 [a]	0.02	-1.02	0.651	
	Pulse	0.01	0.02	0.62	0.645	
	Full tandem	0.02	0.02	1.39	0.185	
	Course walking time	-0.01 [a]	0.01	-0.96	0.931	
	Repeated chair stands time	-0.03 [a]	0.02	-1.72	0.130	
	Pulmonary function	0.04	0.02	1.99	0.048*	
Language & Praxis	BMI	0.02	0.02	1.10	0.272	0.135
	Right grip strength	0.07	0.03	2.12	0.037*	
	Left grip strength	0.01	0.03	0.37	0.715	

Table 2 (continued)

Cognitive performance	Physical health indicators	β	SE	t-value	*p*-value	R^2
	Systolic	-0.02 [a]	0.03	-0.49	0.754	
	Diastolic	0.01	0.03	0.39	0.695	
	Pulse	-0.03 [a]	0.02	-1.46	0.220	
	Full tandem	0.03	0.02	1.34	0.185	
	Course walking time	0.03	0.03	1.02	0.931	
	Repeated chair stands time	-0.02 [a]	0.02	-0.74	0.551	
	Pulmonary function	0.08	0.02	3.31	0.001**	

Note False discovery rate correction was applied: * $p<0.05$; ** $p<0.01$; *** $p<0.001$; [a] Lower scores indicate better cognitive performance; BMI = Body mass index; BP = Blood pressure

cognition (β = 0.04, $p = 0.020$), episodic memory (β = 0.03, $p = 0.018$), executive function (β = 0.05, $p = 0.002$), and orientation (β = 0.06, $p = 0.001$). Longer time required for repeated chair stands was found to be associated with worse episodic memory (β = -0.04, $p = 0.003$), executive function (β = -0.04, $p = 0.004$), and verbal fluency (β = -0.05, $p = 0.004$). For blood pressure, higher systolic pressure was associated with poorer executive function (β = -0.05, $p = 0.008$). For balance tests, success in full tandem was associated with better executive function (β = 0.02, $p = 0.025$). There was no significant association identified between cognitive performance and course walking time, pulse, diastolic pressure, or left grip strength.

Sensitivity analysis

As shown in Supplementary Table S2, the results for episodic memory, executive functioning, and orientation remained consistent in GEE models. Full-dimensional associations of pulmonary function with cognitive performance were still supported (β range between 0.03 and 0.06, $p < 0.005$). Significant associations of right grip strength with all three domains of cognitive performance were also supported (β range between 0.05 and 0.06, $p < 0.008$). As shown in Supplementary Table S4, significant association of right grip strength with cognitive performance only existed in right-hand-dominant participants (β ranged between 0.04 and 0.14, $p < 0.05$), while hand grip strengths of both hands were not significantly associated with cognitive performance in left-hand-dominant participants.

Subgroup analysis

As presented in Supplementary Table S3, subgroup analysis by sex demonstrated that non-invasive physical health indicators are primarily more important factors associated with cognitive performance for males compared to females. In females, apart from pulmonary function and right grip strength, lower pulse was significantly associated with better verbal fluency, and higher BMI was significantly associated with better executive function (β = 0.05, SE = 0.02, $p = 0.001$). Language-and-praxis was not significantly associated with any physical health indicators in females. In male participants, all domains of cognitive performance were significantly associated with physical health indicators.

Discussion

The present study established a comprehensive profile of non-invasive physical health indicators in association with subsequent cognitive performance in older Chinese adults through a longitudinal design. The results indicated varying associations of different physical health indicators with the spectrum of cognitive performance. Pulmonary function was identified as having consistent associations with all domains of the cognitive performance. Right grip strength also emerged as having consistent associations with most cognitive domains, except general cognition. Moreover, the associations between physical health indicators and cognitive performance were influenced by sex. Notably, the associations of physical health indicators with cognitive performance were more pronounced in males than in females.

Among various non-invasive physical health indicators, pulmonary function demonstrated itself as the most important factor associated with subsequent cognitive performance, as lower pulmonary function was significantly associated with poorer outcomes across all cognitive domains in our study. This finding aligns with previous studies identifying a significant association of poorer pulmonary function with higher risks of mild cognitive impairment and dementia in middle-aged and older adults [36, 37]. Our study further substantiated the full-dimensional association between pulmonary function and cognitive performance taking into account other physical health indicators. Therefore, pulmonary function might be treated as a potential full-dimensional risk factor for early screening of mild cognitive impairment in older adults.

One possible explanation for the association between pulmonary function and cognitive performance is interplay of the endocrine, autonomic, and motor control systems, which may be collectively associated with both respiration and cognitive functions [38]. Another explanation involves lifestyle factors such as excessive smoking and reduced physical activity, both linked to poor pulmonary function and cognitive performance. For instance, evidence from British civil servants indicated that smoking, a known risk factor for poor lung function, was associated with cognitive decline in old age [39], while evidence from a 44-year longitudinal study found that physical activity was associated with a lower risk of dementia [40]. Therefore, there are intricate associations between pulmonary function and cognitive performance in older adults, which emphasizes the significance of employing a comprehensive strategy for promoting health and preventing diseases.

Apart from pulmonary function, our study suggested that right grip strength might be an indicator for cognitive impairment in the domain of episodic memory, executive function, verbal fluency, orientation, and language-and-praxis. This finding aligns with previous studies linking grip strength to brain structure and function [41] and showing that grip strength training can lead to changes in brain activation patterns [42]. It is possible that grip strength reflects the functioning of neural pathways involved in various cognitive performance. One explanation for the association between grip strength and cognitive performance concerns its role as a marker of muscle mass and physical activity, both of which have been shown to be protective against cognitive decline [43]. Another explanation is that the mechanisms linking grip strength and cognitive performance may both rely on the cortical hemodynamic pathways, such as oxyhemoglobin and deoxyhemoglobin [44]. Although an overlap of brain regions between muscle strength and cognitive performance can be speculated from the previous studies [45, 46], direct imaging evidence is lacking. Future research could use an intuitive research design to further investigate these potential explanations. One interesting finding concerning grip strength is that the left grip strength is not significantly associated with any cognitive performance. Our results from sensitivity analysis further indicated significant association between grip strength and cognitive performance only existed in right-hand-dominant participants. The results should be interpreted with caution as only 336 participants were left-handed, which reduced the statistical power to detect significant effects. Nevertheless, the effect sizes of grip strengths from two hands in left-handed participants are generally similar, while right-hand grip strength having relatively greater associations with general cognition than left-hand grip strength, potentially supporting the more important role of right-hand grip strength in association with cognitive functions regardless of handedness. Alongside previous evidence suggesting cognitive benefits of right-handedness [47], our results further indicated stronger association between right-hand usage and cognitive performance. Future studies with a more balanced sample are still required to further explore the interplay between handedness and grip strength in relation to cognitive functions.

Another unexpected finding was the positive association between BMI and certain domains of cognitive performance, which conflicts with previous evidence suggesting BMI as a risk factor for mild cognitive impairment [48]. This discrepancy might be attributed to the inclusion of other physical health indicators in our model. BMI has been shown to be negatively associated with other physical health indicators, including pulmonary function [49], which our results demonstrated to be a consistent risk factor for all cognitive domains. Therefore, the potential negative effects of BMI on cognitive performance might be accounted for by pulmonary function in our models. Moreover, the positive associations of BMI might be attributed to the sample of Chinese older people. It has been shown that undernutrition is a more prevalent issue in older Chinese people compared to overnutrition, and higher BMI is associated with higher socio-economic status [50], which is a protective factor for cognitive functions [51]. Therefore, the positive associations between BMI and cognitive functions in our results might be attributed to a higher socio-economic status. Future studies might further explore the role of BMI in cognitive performance controlling for other physical health indicators in sample from different regions.

Another interesting finding is that the associations between physical health indicators and cognitive performance are generally more pronounced in males compared to females. One potential explanation for this sex-related effect is that males have higher levels of testosterone, which is associated with greater muscle mass and strength [52]. Testosterone may also have neuroprotective effects [53], which could contribute to the male-specific relationship between strengths-related physical health indicators and cognitive performance. Nevertheless, more studies are still needed to further investigate the role of testosterone in the relationship between non-invasive physical health indicators and cognitive performance.

The results of our study should be interpreted cautiously due to few limitations. One primary limitation is the potential for selection bias. Participants with physical disabilities, brain damage, mental retardation, or memory-related disease were excluded in this study, given that the participants included in the study were healthier than those excluded. This may have facilitated the characterization of the associations between non-invasive physical health indicators and cognitive performance. Moreover, the cognitive performance measurements utilized in the CHARLS study were not capable of directly identify mild cognitive impairment. Therefore, further investigations are still required to explore the potential predictive effects of non-invasive physical health indicators and the risk of developing mild cognitive impairment. Second, since China is a developing country, more than 50% of the CHARLS participants did not finish primary school while more than 30% of them were illiterate in our sample. The CHARLS participants were less educated, which might have led to lower score on cognitive tests. Therefore, the association between non-invasive physical health indicators on cognitive performance might be underestimated as the variance of cognitive performance in less educated participants might be too small for us to detect the associations. Regarding the establishment of causal relationship, the CHALRS dataset only enabled consideration of outcome values at baseline for episodic memory, executive function, and orientation. Moreover, since our study focused on physical health indicators that can be easily and objectively measured through routine physical examinations, we did not account for certain key factors, such as lifestyle behaviors, in our statistical model. Therefore, future studies are still required to further explore the longitudinal associations between physical health indicators and cognitive performance with baseline outcome data and more comprehensive adjustments to facilitate better causal inference. Future studies should further explore the predictive effects of non-invasive physical health indicators on cognitive performance in a more well-educated sample.

Conclusions

In conclusion, non-invasive physical health indicators are longitudinally associated with all domains of cognitive performance in the older adult population, while these associations vary between sexes. The significant role of pulmonary function in relation to cognitive functions was particularly highlighted. Our findings established a profile of non-invasive physical health indicators in association with a comprehensive range of subsequent cognitive performance, facilitating timely and efficient screening for mild cognitive impairment in older adults. Future explorations involving non-invasive physical health indicators in early risk screening systems for mild cognitive impairment are warranted. Further research is also needed to elucidate the mechanisms underlying the comprehensive relationship between physical and cognitive health.

Abbreviations

MCI	Mild cognitive impairment
CHARLS	The China Health and Retirement Longitudinal Study
BMI	Body mass index
WR	Word recall
DR	Delayed recall
WRE	Wordlist recognition
MMSE	Mini Mental State Exam

Supplementary Information

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Supplementary Material 1

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Not applicable.

Author contributions

XW conceptualized the study, conducted data curation, formal analysis, and investigation, and contributed to the manuscript writing - original draft and review & editing. CL conceptualized the study, conducted data curation formal analysis, and investigation, and contributed to the manuscript writing - original draft and review & editing. DL wrote the original draft and contributed to the methodology and formal analysis. JC and YJ reviewed and edited the manuscript. JL contributed to data curation, investigation, methodology, supervision, and writing - review & editing. BL contributed to investigation, methodology, supervision, and writing -review & editing. YZ contributed to the investigation, methodology, supervision, and writing - review & editing.

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Data availability

The data used in this study was drawn from an open accessed dataset: the China Health and Retirement Longitudinal Study (CHARLS; https://charls.pku.edu.cn/).

Declarations

Ethics approval and consent to participate

The institutional review board at Peking University granted the CHARLS ethical approval. Written informed consent was given by each participate who agreed to take part in the study.

Consent for publication

The present study contains no identifiable individual personal data.

Competing interests

The authors declare no competing interests.

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References

1. Bloom DE, Canning D, Lubet A. Global Population Aging: facts, challenges, solutions & perspectives. Daedalus. 2015;144(2):80–92.
2. Sciubba JD. Population Aging as a global issue. In.: Oxford University Press; 2020.

3. Chen P, Cai H, Bai W, Su Z, Tang YL, Ungvari GS, Ng CH, Zhang Q, Xiang YT. Global prevalence of mild cognitive impairment among older adults living in nursing homes: a meta-analysis and systematic review of epidemiological surveys. Transl Psychiatry. 2023;13(1):88.
4. Lu Y, Liu C, Yu D, Fawkes S, Ma J, Zhang M, Li C. Prevalence of mild cognitive impairment in community-dwelling Chinese populations aged over 55 years: a meta-analysis and systematic review. BMC Geriatr. 2021;21(1):10.
5. Hanmo Y. Dynamic Trend of China's Population Ageing and New characteristics of the Elderly. Popul Res. 2022;46(5):104–16.
6. Deng Y, Zhao S, Cheng G, Yang J, Li B, Xu K, Xiao P, Li W, Rong S. The prevalence of mild cognitive impairment among Chinese people: a Meta-analysis. Neuroepidemiology. 2021;55(2):79–91.
7. Song D, Yu DS, Li PW, He G, Sun Q. Correlates of Health-Related Quality of Life among Chinese older adults with mild cognitive impairment. Clin Interv Aging. 2019;14:2205–12.
8. Bauer CM, Cabral HJ, Killiany RJ. Multimodal Discrimination between Normal Aging, Mild Cognitive Impairment and Alzheimer's Disease and Prediction of Cognitive Decline. Diagnostics (Basel) 2018, 8(1).
9. Teipel S, Drzezga A, Grothe MJ, Barthel H, Chételat G, Schuff N, Skudlarski P, Cavedo E, Frisoni GB, Hoffmann W, et al. Multimodal imaging in Alzheimer's disease: validity and usefulness for early detection. Lancet Neurol. 2015;14(10):1037–53.
10. Muadmanee W, Hiransuthikul A, Chunharas C, Thongkam A, Petchlorlian A, Praditpornsilpa K. Compact MoCA: a shortened alternative for MCI screening among healthy aging individuals. Alzheimer's Dement. 2021;17(S6):e050413.
11. Han Y, He Y, Lyu J, Yu C, Bian M, Lee L. Aging in China: perspectives on public health. Global Health J. 2020;4(1):11–7.
12. Rosano C, Simonsick EM, Harris TB, Kritchevsky SB, Brach J, Visser M, Yaffe K, Newman AB. Association between physical and cognitive function in healthy elderly: the health, aging and body composition study. Neuroepidemiology. 2005;24(1–2):8–14.
13. Toots ATM, Taylor ME, Lord SR, Close JCT. Associations between Gait speed and cognitive domains in older people with cognitive impairment. J Alzheimers Dis. 2019;71(s1):S15–21.
14. Gafni T, Gabriel KP, Shuval K, Yaffe K, Sidney S, Weinstein G. Physical activity trajectories, autonomic balance and cognitive function: the coronary artery Risk Development in Young adults (CARDIA) study. Prev Med. 2022;164:107291.
15. Altschul DM, Wraw C, Der G, Gale CR, Deary IJ. Hypertension development by midlife and the roles of Premorbid cognitive function, sex, and their Interaction. Hypertension. 2019;73(4):812–9.
16. Kim GR, Sun J, Han M, Nam CM, Park S. Evaluation of the directional relationship between handgrip strength and cognitive function: the Korean Longitudinal Study of Ageing. Age Ageing. 2019;48(3):426–32.
17. Duggan EC, Graham RB, Piccinin AM, Jenkins ND, Clouston S, Muniz-Terrera G, Hofer SM. Systematic review of pulmonary function and cognition in aging. J Gerontol B Psychol Sci Soc Sci. 2020;75(5):937–52.
18. Chiesa ST, Norris T, Garfield V, Richards M, Hughes AD. Early-life cumulative exposure to excess bodyweight and midlife cognitive function: longitudinal analysis in three British birth cohorts. Lancet Healthy Longev. 2024;5(3):e204–13.
19. Lai X, Sun J, He B, Li D, Wang S, Zhan S. Associations between pulmonary function and cognitive decline in the middle-aged and older adults: evidence from the China Health and Retirement Longitudinal Study. Environ Health Prev Med. 2022;27:48.
20. Liu Y, Cao X, Gu N, Yang B, Wang J, Li C. A prospective study on the Association between Grip Strength and cognitive function among Middle-aged and Elderly Chinese participants. Front Aging Neurosci. 2019;11:250.
21. Studenski S, Perera S, Patel K, Rosano C, Faulkner K, Inzitari M, Brach J, Chandler J, Cawthon P, Connor EB, et al. Gait speed and survival in older adults. JAMA. 2011;305(1):50–8.
22. Cesari M, Kritchevsky SB, Penninx BW, Nicklas BJ, Simonsick EM, Newman AB, Tylavsky FA, Brach JS, Satterfield S, Bauer DC, et al. Prognostic value of usual gait speed in well-functioning older people–results from the Health, Aging and Body Composition Study. J Am Geriatr Soc. 2005;53(10):1675–80.
23. VanderWeele TJ, Jackson JW, Li S. Causal inference and longitudinal data: a case study of religion and mental health. Soc Psychiatry Psychiatr Epidemiol. 2016;51(11):1457–66.
24. Zhao Y, Hu Y, Smith JP, Strauss J, Yang G. Cohort profile: the China Health and Retirement Longitudinal Study (CHARLS). Int J Epidemiol. 2014;43(1):61–8.
25. McArdle JJ, Fisher GG, Kadlec KM. Latent variable analyses of age trends of cognition in the Health and Retirement Study, 1992–2004. Psychol Aging. 2007;22(3):525–45.
26. Fong TG, Fearing MA, Jones RN, Shi P, Marcantonio ER, Rudolph JL, Yang FM, Kiely DK, Inouye SK. Telephone interview for cognitive status: creating a crosswalk with the Mini-mental State Examination. Alzheimers Dement. 2009;5(6):492–7.
27. Hall KS, Hendrie HC, Brittain HM, Norton JA, et al. The development of a dementia screening interview in two distinct languages. Int J Methods Psychiatr Res. 1993;3(1):1–28.
28. Salmon DP, Bondi MW. Neuropsychological assessment of dementia. Annu Rev Psychol. 2009;60:257–82.
29. Belleville S, Fouquet C, Hudon C, Zomahoun HTV, Croteau J. Neuropsychological measures that predict progression from mild cognitive impairment to Alzheimer's type dementia in older adults: a systematic review and Meta-analysis. Neuropsychol Rev. 2017;27(4):328–53.
30. Schmerold K, Bock A, Peterson M, Leaf B, Vennergrund K, Pasnak R. The relations between patterning, executive function, and mathematics. J Psychology: Interdisciplinary Appl. 2017;151(2):207–28.
31. Schechter I, Korn C, Yungreis A, Koren R, Sternfeld R, Motlis H, Bergman M. The Word Retrieval Fluency Test: what does it assess? Scand J Rehabil Med Suppl. 1985;12:76–9.
32. Marko M, Michalko D, Dragašek J, Vančová Z, Jarčušková D, Riečanský I. Assessment of Automatic and Controlled Retrieval using Verbal Fluency tasks. Assessment. 2023;30(7):2198–211.
33. Folstein MF, Robins LN, Helzer JE. The Mini-mental State Examination. Arch Gen Psychiatry. 1983;40(7):812–812.
34. Buuren Sv, Groothuis-Oudshoorn K, Vink G, Schouten R, Robitzsch A, Rockenschaub P, Doove L, Jolani S, Moreno-Betancur M, White I et al. mice: Multivariate Imputation by Chained Equations. In.; 2023.
35. Benjamini Y, Hochberg Y. Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. J Royal Stat Soc Ser B. 1995; 51(1):289-300.
36. Wang J, Dove A, Song R, Qi X, Ma J, Bennett DA, Xu W. Poor pulmonary function is associated with mild cognitive impairment, its progression to dementia, and brain pathologies: a community-based cohort study. Alzheimers Dement. 2022;18(12):2551–9.
37. Pathan SS, Gottesman RF, Mosley TH, Knopman DS, Sharrett AR, Alonso A. Association of lung function with cognitive decline and dementia: the atherosclerosis risk in communities (ARIC) Study. Eur J Neurol. 2011;18(6):888–98.
38. Richards M, Strachan D, Hardy R, Kuh D, Wadsworth M. Lung function and cognitive ability in a longitudinal birth cohort study. Psychosom Med. 2005;67(4):602–8.
39. Sabia S, Elbaz A, Dugravot A, Head J, Shipley M, Hagger-Johnson G, Kivimaki M, Singh-Manoux A. Impact of smoking on cognitive decline in early old age: the Whitehall II cohort study. Arch Gen Psychiatry. 2012;69(6):627–35.
40. Najar J, Östling S, Gudmundsson P, Sundh V, Johansson L, Kern S, Guo X, Hällström T, Skoog I. Cognitive and physical activity and dementia: a 44-year longitudinal population study of women. Neurology. 2019;92(12):e1322–30.
41. Carson RG. Get a grip: individual variations in grip strength are a marker of brain health. Neurobiol Aging. 2018;71:189–222.
42. Bonzano L, Pedullà L, Tacchino A, Brichetto G, Battaglia MA, Mancardi GL, Bove M. Upper limb motor training based on task-oriented exercises induces functional brain reorganization in patients with multiple sclerosis. Neuroscience. 2019;410:150–9.
43. Grimmer M, Riener R, Walsh CJ, Seyfarth A. Mobility related physical and functional losses due to aging and disease - a motivation for lower limb exoskeletons. J Neuroeng Rehabil. 2019;16(1):2.
44. Herold F, Behrendt T, Törpel A, Hamacher D, Müller NG, Schega L. Cortical hemodynamics as a function of handgrip strength and cognitive performance: a cross-sectional fNIRS study in younger adults. BMC Neurosci. 2021;22(1):10.
45. Rosano C, Snitz BE. Predicting dementia from decline in Gait Speed: are we there yet? J Am Geriatr Soc. 2018;66(9):1659–60.
46. Christensen H, Mackinnon AJ, Korten A, Jorm AF. The common cause hypothesis of cognitive aging: evidence for not only a common factor but also specific associations of age with vision and grip strength in a cross-sectional analysis. Psychol Aging. 2001;16(4):588–99.
47. Somers M, Shields LS, Boks MP, Kahn RS, Sommer IE. Cognitive benefits of right-handedness: a meta-analysis. Neurosci Biobehav Rev. 2015;51:48–63.
48. Kim S, Kim Y, Park SM. Body Mass Index and decline of cognitive function. PLoS ONE. 2016;11(2):e0148908.

49. Sun Y, Zhang Y, Liu X, Liu Y, Wu F, Liu X. Association between body mass index and respiratory symptoms in US adults: a national cross-sectional study. Sci Rep. 2024;14(1):940.
50. Zhou J, Liu S, Zhang Z, Ye L, Wang J, Chen C, Cui J, Qiu Y, Wu B, Lyu Y, et al. Distribution characteristics of body mass index among Chinese oldest-old aged 80 years and above [In Chinese]. Chin J Epidemioloy. 2023;44(06):855–61.
51. Migeot J, Calivar M, Granchetti H, Ibáñez A, Fittipaldi S. Socioeconomic status impacts cognitive and socioemotional processes in healthy ageing. Sci Rep. 2022;12(1):6048.
52. Mudali S, Dobs AS. Effects of testosterone on body composition of the aging male. Mech Ageing Dev. 2004;125(4):297–304.
53. Siddiqui AN, Siddiqui N, Khan RA, Kalam A, Jabir NR, Kamal MA, Firoz CK, Tabrez S. Neuroprotective role of Steroidal Sex hormones: an overview. CNS Neurosci Ther. 2016;22(5):342–50.

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