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Gender differences in the correlation between body mass index and cognitive impairment among the community-dwelling oldest-old in China: a cross-sectional study

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ABSTRACT

Objective This study investigates gender differences in the correlation between body mass index (BMI) and cognitive impairment among Chinese community-dwelling oldest-old.

Setting Twenty-three provinces in China. Participants' mini-mental state examination (MMSE) scores <24 were considered cognitive impairment. Furthermore, the assessment standards of BMI status were classified into four categories: obese (BMI >30), overweight (25≤BMI≤30), normal (18.5≤BMI<25) and underweight (BMI <18.5).

Participants A total of 9218 older adults (age 80+) were included from the 2018 wave of Chinese Longitudinal Healthy Longevity Study.

Methods Cognitive impairment, BMI and other covariates consisted of the sociodemographic variables, health behaviours and health status were collected. Cognitive impairment was assessed by the MMSE. Inverse probability weighting procedure was adopted to deal with bias due to dropout. Logistic regression was conducted to examine the correlation between BMI and cognitive impairment.

Results Among 9218 respondents, 3837 were males. Overall, the percentage of participants with cognitive impairment was 44.7%, with 32.1% among males and 53.7% among females. After controlling for other variables, males who were either overweight or underweight and females who were underweight were found to have higher risk of cognitive impairment among the oldest-old. Age, education, economic status, physical activity, activities of daily living, hypertension as well as heart disease were the predicting factors of cognitive impairment.

Conclusions The relationship between BMI and cognitive impairment differs between male and female oldest-old, suggesting that we should pay attention to different BMI groups and adopt precise prevention strategies based on gender.

STRENGTHS AND LIMITATION OF THIS STUDY

- ⇒ This study has a large randomly selected sample of 9218 community-dwelling oldest-old (80+) from 23 provinces in China.
- ⇒ Inverse probability weighting procedure was conducted to deal with bias due to dropout.
- ⇒ Four models were used to examine the effects of different covariates on the correlation between body mass index and cognitive impairment among male/female oldest-old.
- ⇒ The cross-sectional design precludes any causal relationship.
- ⇒ Some self-reported information may lead to the possibility of bias.

INTRODUCTION

With the growing ageing society, the research on cognitive impairment has increased at an alarming rate. Because cognitive impairment is closely related to dementia, which is the fifth leading cause of death globally[1] and the troublesome disease with a huge burden.[2 3] Furthermore, epidemiological data reported that dementia influenced 5%–10% of seniors in the developed countries and the prevalence doubled every 5 years.[4] In addition, cognitive impairment was more likely to develop into dementia in the coming 2years[5] and the conversion rate from cognitive impairment to dementia was 39.2% in a meta-analysis of 41 cohort studies.[6] As a common age-related disease, the prevalence of cognitive impairment will be on the rise with the development of ageing. Meanwhile, there is no ultimate treatment of dementia and cognitive impairment,[7] effective and convenient prevention strategies are extremely important, especially among the oldest-old who were associated with a high risk of cognitive impairment[8] and frailty which may lead to a homeostatic failure of complex systems.[9] Therefore, it is vital to identify risk factors among the oldest-old to decrease the incidence of cognitive impairment and subsequent dementia. Previous studies identified predicting factors related to cognitive impairment,[10] such as sociodemographic variables (age, education, gender, marital status, economic status), health behaviours (regular exercise, smoking, drinking, physical activities) and health status (body mass index (BMI), non-communicable disease, activity of daily living (ADL)).[3 11–13]

Meanwhile, the prevalence of overweight and obesity is increasing all over the world, including older adults.[14] It is reported that 3.3 billion people (>50%) would be overweight and obese by 2030.[15] BMI is usually adopted as an indicator of general obesity status.[16] Evidence shows a significant relationship between BMI and cognitive impairment.[7 11 17 18] Previous studies reported that BMI was associated with structural integrity of a brain region connecting temporal and frontal lobes among older adults, which might influence their cognitive function.[19 20] In addition, the comorbidities associated with obesity and overweight such as hypertension, diabetes, cardiovascular disease might also explain the association between BMI and cognitive impairment.[21] But the results were controversial due to different physiological characteristics.[13 22] Furthermore, another cohort study indicated the association between brain metabolism/connectivity and BMI among male and female older adults.[23] However, fewer studies have investigated gender differences in the correlation between BMI and cognitive impairment among seniors living in rural areas in Shandong province in China.[22] Surprisingly, although there are great disparities existing in physical and mental health,[24] educational opportunities,[25] changes in oestrogen levels during menopause[26] and risk of dementia and cognitive impairment[2 26 27] between men and women, no study so far has focused on the gender differences of the relationship between BMI and cognitive impairment among Chinese community-dwelling oldest-old. Therefore, the purpose of our study is to investigate such relationship between men and women among Chinese oldest-old with a relatively large nationwide sample. We hypothesise that (1) BMI is associated with cognitive impairment among community-dwelling oldest-old in China; and (2) the association between BMI and cognitive impairment varies by gender.

METHODS

Study sample

Data were drawn from the most recent wave of Chinese Longitudinal Healthy Longevity Survey (CLHLS) in 2018. The CLHLS was the first and ongoing national survey with largest number of the community-dwelling oldest-old in China which conducted in randomly selected half of the cities/counties in 23 out of 31 provinces covering 85% of the population in China. All centenarians (100+) who voluntarily agreed to participate were included in the sample. Based on gender and place of residence, one octogenarian (80–89) and nonagenarian (90–99) were randomly interviewed which ensured the adequate number of randomly selected oldest seniors in China.[28] Furthermore, it has been followed up every 3 years since 1998, which was proved to be of good quality.[3 28] The study followed the principles expressed in the Declaration of Helsinki. The questions of mini-mental state examination (MMSE) were answered by older adults themselves; other questions would be answered by proxy respondents if the oldest-old were unable to answer.

MEASUREMENTS

Cognitive assessment

MMSE was considered as one of the common ways to assess cognitive function worldwide.[7 29] MMSE in the study was measured by Chinese version of the MMSE, which was proven to be of good reliability and validity.[3] It provided a comprehensive assessment consisted of orientation, attention, calculation and language as well as memory. The scores of MMSE ranged from 0 to 30, with a higher score representing better cognitive function. Participants' MMSE scores <24 was considered cognitive impairment; otherwise, the seniors were defined with normal cognitive function.[18 30 31]

Body mass index

BMI was calculated using weight (kg) divided by height (m^2) that were measured by interviewers. The assessment standards of BMI status were classified into four categories according to the literature[28 30 32 33]: obese (BMI >30), overweight (25≤BMI≤30), normal (18.5≤BMI<25) and underweight (BMI<18.5).

COVARIATES

Covariates consisted of sociodemographic variables (age, years of schooling, marital status, economic status), health behaviour variables (physical activity, smoking, drinking) and health status variables (ADL, hypertension, dyslipidaemia, diabetes, heart disease, stroke, cancer). Marital status was defined as 'single' if they were never married, widowed or divorced. Economic status was assessed by the question 'how do you rate your economic status compared with other local people?' and divided into five groups, which are very poor, poor, average, rich and very rich.[28] ADL was measured by Katz Activity of Daily Living Scale, which included six items as follows: dressing, feeding, bathing, walking inside, toileting, bladder and bowel control.[34] Each item had two response choices: 'dependent' and 'independent'. ADL was categorised as number of ADL disability (0, 1–2, 3–4, 5–6).[35 36]

STATISTICAL ANALYSIS

All statistical analyses were performed individually among male and female subgroups with statistical package SPSS V.22.0. χ^2 tests were used to examine cognitive impairment differences in independent variables between male and female oldest-old. Logistic regression was applied to explore the relationship between BMI and cognitive impairment among the participants (80+), and to identify influential factors in male and female seniors, respectively. All reported CIs were calculated at the 95% level. The significant difference was defined as p<0.05. Inverse probability weighting procedure was conducted to deal with bias due to dropout.

Four models were used to examine how different covariates related to the correlation. First, model 1 was run without adjustment. Next, three nested models were adopted: included covariates for sociodemographics (model 2), then adding 'health behaviour' variables (model 3) and the final model further included 'health status' variables (model 4).[28]

Patient and public involvement

Neither patients nor the public had roles in the design, collection, analysis and interpretation of data or in writing the manuscript.

RESULTS

Among 15 874 subjects in the 2018 wave of CLHLS, 10 419 were aged 80 years old and above. After eliminating participants who had a round back, inverse probability weighting procedure was conducted to deal with bias due to dropout. The final sample size was 9218, which included 3837 males and 5381 females. The overall proportion of cognitive impairment among the oldest-old was 44.7%, with 32.1% among males and 53.7% among females.

Table 1 shows basic characteristics of 9218 samples and differences of cognitive impairment between men and women. For all oldest-old, BMI, gender, age, years of schooling, marital status, economic status, physical activity, smoking, drinking, ADL disability, hypertension, dyslipidaemia, diabetes, heart disease and cancer were associated with cognitive impairment. Furthermore, the differences among males and females were also described, respectively. For males, all variables were related to cognitive impairment except smoking, dyslipidaemia, stroke and cancer. For females, all variables other than drinking, and stroke were correlated with cognitive impairment.

Table 2 reported the correlation between BMI and cognitive impairment among the oldest-old. Results from model 1 indicated that the prevalence of cognitive impairment among seniors (80+) who were underweight were significantly higher than that among the oldest-old whose BMIs were normal. Meanwhile, the risk of cognitive impairment among the oldest-old who were overweight was significantly lower than seniors with normal BMI. Model 2 showed that when controlling for other variables, the incidence of cognitive impairment was statistically higher among the oldest-old who were underweight (OR=1.296, 95% CI: 1.141 to 1.471, p=0.002) than normal group.

Table 3 demonstrated logistic regression analysis of cognitive impairment among male seniors (80+) in China. The results indicated that the risk of cognitive impairment among overweight and underweight subgroup was higher than normal one; the OR increased from 1.013 (95% CI:0.824 to 1.245) in the unadjusted model to 1.330 (95% CI: 1.041 to 1.699) in the final fully adjusted model among overweight subgroup; the OR decreased from 1.691 (95% CI: 1.410 to 2.027) in the unadjusted model to 1.466 (95% CI: 1.184 to 1.816) in the final fully adjusted model among overweight subgroup. In addition, age, years of schooling, economic status, physical activity, smoking, drinking, ADL disability, hypertension, heart disease and stroke were important influential factors associated with cognitive impairment among male oldest-old.

As shown in table 4, we found that the possibility of cognitive impairment in underweight group was higher than normal one among female oldest-old; the OR decreased from 1.776 (95% CI: 1.550 to 2.035) in the unadjusted model to 1.217 (95% CI: 1.039 to 1.425) in the final fully adjusted model. However, there was no significant difference in overweight female subgroup. Furthermore, age, years of schooling, economic status, physical activity, ADL disability, hypertension, dyslipidaemia and heart disease were associated with cognitive impairment among female oldest-old.

DISCUSSION

Using a nationwide data, we found a significant relationship between BMI and cognitive impairment among Chinese community-dwelling oldest-old, which implying that BMI might be important as a convenient screening tool of cognitive impairment among the oldest-old. Furthermore, there are gender differences in the correlation between BMI and cognitive impairment. This study indicated that underweight/overweight group was associated with relatively higher possibility of cognitive impairment in male oldest-old adults over 80 years old, while the relationship was only found in underweight female oldest-old, suggesting that we should focus on different BMI group and adopt different prevention strategies between men and women.

Our findings demonstrated that the prevalence of cognitive impairment among the oldest-old was 44.7%, with 32.1% among males and 53.7% among females. The incidence of cognitive impairment is higher than 22.45% in Taiwan,[37] 25.2% in Beijing[38] and 37.8% in Iran.[29] The reason may be related to the age of participants. In addition, our results showed that the prevalence of cognitive impairment among female seniors (80+) was significantly higher than males.[27 39] Respecting the differences between male and female oldest-old, possible explanations can be attributed to educational opportunities and changes in oestrogen levels during menopause.[25 26 40] The levels of steroids, such as testosterone and oestrogen which might protect cognitive function,[41] are higher among male oldest-old adults than postmenopausal females. The results indicate that we should pay attention to cognitive function and adopt early screening among the oldest-old, especially in female oldest-old, because it is a common age-related disease which is complex for individuals to

Table 1 Description of cognitive impairment among the oldest-old in China, CLHLS 2018

	Total (n=9218)		Males (n=3837)		Females (n=5381)	
	Normal cognition	Cognitive impairment	Normal cognition	Cognitive impairment	Normal cognition	Cognitive impairment
N (%)						
Sociodemographics						
Age						
80–89	2884 (76.2)	899 (23.8)***	1497 (83.4)	298 (16.6)***	1388 (69.8)	601 (30.2)***
90–99	1591 (51.0)	1526 (49.0)	879 (61.0)	561 (39.0)	712 (42.5)	965 (57.5)
100+	619 (26.7)	1699 (73.3)	230 (38.2)	372 (61.8)	389 (22.7)	1326 (77.3)
Years of schooling						
0	2034 (41.8)	2830 (58.2)***	594 (50.9)	573 (49.1)***	1440 (38.9)	2257 (61.1)***
1–6	2329 (67.4)	1129 (32.6)	1457 (72.6)	550 (27.4)	872 (60.1)	578 (39.9)
7+	731 (81.6)	165 (18.4)	554 (83.6)	109 (16.4)	178 (75.9)	56 (24.1)
Marital status						
Single	3350 (48.7)	3531 (51.3)***	1325 (60.6)	863 (39.4)***	2025 (43.1)	2668 (56.9)***
Couple	1745 (74.6)	592 (25.4)	1280 (77.6)	369 (22.4)	465 (67.5)	223 (32.5)
Economic status						
Very rich	180 (71.6)	71 (28.4)***	114 (81.2)	26 (18.8)***	66 (59.5)	45 (40.5)***
Rich	1056 (67.4)	510 (32.6)	587 (77.0)	176 (23.0)	469 (58.4)	334 (41.6)
Average	3430 (53.3)	3011 (46.7)	1693 (66.5)	855 (33.5)	1737 (44.6)	2156 (55.4)
Poor	380 (45.7)	452 (54.3)	188 (55.7)	149 (44.3)	192 (38.8)	303 (61.2)
Very poor	48 (37.6)	80 (62.4)	23 (46.9)	26 (53.1)	25 (31.9)	54 (68.1)
Gender						
Male	2605 (67.9)	1232 (32.1)***				
Female	2489 (46.3)	2892 (53.7)				
Health behaviour						
Physical activity						
No	3391 (49.2)	3502 (50.8)***	1587 (61.6)	990 (38.4)***	1805 (41.8)	2512 (58.2)***
Yes	1703 (73.3)	622 (26.7)	1018 (80.8)	242 (19.2)	684 (64.3)	380 (35.7)
Smoking						
Seldom	4351 (53.9)	3724 (46.1)***	1991 (67.9)	943 (32.1)	2360 (45.9)	2781 (54.1)*
Often	743 (65.0)	400 (35.0)	614 (68.0)	289 (32.0)	129 (53.8)	111 (46.2)
Health behaviour						
Drinking						
No	4345 (53.6)	3768 (46.4)***	2013 (66.2)	1028 (33.8)***	2332 (46.0)	2739 (54.0)
Yes	749 (67.8)	356 (32.2)	592 (74.4)	204 (25.6)	157 (50.7)	153 (49.3)
Health status						
Number of ADL disability						
0	4201 (67.8)	1992 (32.2)***	2190 (77.8)	626 (22.2)***	2011 (59.5)	1367 (40.5)***
1–2	679 (40.3)	1005 (59.7)	314 (51.5)	296 (48.5)	365 (34.0)	709 (66.0)
3–4	146 (22.5)	503 (77.5)	69 (31.3)	152 (68.7)	77 (18.1)	351 (81.9)
5–6	68 (9.8)	624 (90.2)	32 (16.8)	158 (83.2)	36 (7.2)	465 (92.8)
Hypertension						
Yes	2157 (62.4)	1299 (37.6)***	1019 (73.9)	360 (26.1)***	1138 (54.8)	939 (45.2)***
No	2937 (51.0)	2825 (49.0)	1586 (64.5)	872 (35.5)	1352 (40.9)	1952 (59.1)
Dyslipidaemia						
Yes	232 (72.1)	90 (27.9)***	88 (69.4)	39 (30.6)	143 (73.8)	51 (26.2)***
No	4862 (54.7)	4034 (45.3)	2517 (67.8)	1193 (32.2)	2346 (45.2)	2841 (54.8)

Continued

Table 1 Continued

	Total (n=9218)		Males (n=3837)		Females (n=5381)	
	Normal cognition	Cognitive impairment	Normal cognition	Cognitive impairment	Normal cognition	Cognitive impairment
Diabetes						
Yes	436 (68.4)	202 (31.6)***	204 (74.6)	70 (25.4)*	232 (63.7)	132 (36.3)***
No	4658 (54.3)	3922 (45.7)	2401 (67.4)	1162 (32.6)	2257 (45.0)	2760 (55.0)
Heart disease						
Yes	923 (64.2)	514 (35.8)***	413 (74.1)	144 (25.9)**	510 (57.9)	371 (42.1)***
No	4171 (53.6)	3610 (46.4)	2192 (66.8)	1088 (33.2)	1979 (44.0)	2521 (56.0)
Stroke						
Yes	494 (56.2)	385 (43.8)	282 (65.1)	151 (34.9)	212 (47.6)	234 (52.4)
No	4600 (55.2)	3739 (44.8)	2323 (68.2)	1081 (31.8)	2277 (46.1)	2658 (53.9)
Cancer						
Yes	68 (65.5)	36 (34.5)*	33 (64.5)	18 (35.5)	35 (66.5)	18 (33.5)**
No	5026 (55.1)	4088 (44.9)	2572 (67.9)	1214 (32.1)	2454 (46.1)	2874 (53.9)
Underweight (BMI <18.5)	911 (42.4)	1236 (57.6)* ***	415 (58.3)	296 (41.7)***	496 (34.6)	940 (65.4)***
Normal (18.5≤BMI<25)	3211 (58.0)	2322 (42.0)	1712 (70.3)	724 (29.7)	1499 (48.4)	1598 (51.6)
Overweight (25≤BMI≤30)	818 (63.9)	461 (36.1)	415 (70.0)	178 (30.0)	403 (58.7)	284 (41.3)
Obesity (BMI >30)	154 (59.7)	104 (40.3)	63 (65.0)	34 (35.0)	91 (56.5)	70 (43.5)

*p<0.05, **p<0.01, ***p<0.001.

ADL, activity of daily living; BMI, body mass index; CLHLS, Chinese Longitudinal Healthy Longevity Survey.

distinguish the disparity between natural ageing and pathological changes.[42]

For male oldest-old, overweight and underweight was significantly associated with a high risk of cognitive impairment, which was partly in agreement with previous studies.[22 39 43] On one hand, overweight is related to high possibility of chronic diseases,[16] especially cardiovascular disease[44] and poorer mobility,[45] which may result in cognitive impairment. Moreover, the relationship between BMI and cognitive impairment in male oldest-old might due to common pathological mechanism: abnormal amyloid precursor protein,[22] which was considered to be the main pathogenic factor for Alzheimer's.[46] On the other hand, underweight is associated with a high risk of malnutrition,[47] micronutrient deficiencies and consequently acceleration of neurodegenerative process,[12] thus leading to declining cognitive function. However, our findings showed that obese was not related to cognitive impairment, which might be explained as follows. The proportion of obese in males were relatively small (2.5%), whereas the overweight males occupied 15.0%. The sample size of obese male was not enough to explain the correlation, suggesting further research being needed for clarification. The findings indicated that it is urgent to focus on overweight males and adopt appropriate prevention strategies.

The female oldest-old in underweight subgroup were more likely to be related to cognitive impairment, which was partly in line with previous studies.[3 11] The possible reasons might be explained in more than one way. First, underweight is associated with a high risk of malnutrition[47] leading to declining cognitive function. Second, overweight is not a risk factor for cognitive impairment, which might be explained in the context of 'obesity paradox', a hypothesis that obesity can protect against cognitive impairment.[48] Although the mechanisms of 'obesity paradox' remain unclear, this study may be because of poor education status or unique steroid hormones among females.[25 49] Previous studies showed that education can explain 39% of the risk of cognitive impairment.[26] Moreover, education status of female oldest-old in China is significantly lower than that of males because of historical and cultural factors.[25] In addition, hormone changes of females may be related to a high risk of cognitive impairment based on the evidence that hormone replacement therapy is benefit for protecting against dementia.[49] There are other gender differences in both biological and social perspectives, such as the distribution and type of oestrogen receptors in the brains.[40] In conclusion, above factors may weaken the relationship between BMI and cognitive impairment among obese females. Hence, not only should we focus on female oldest-old with BMI under 18.5 kg/m^2, but we also need to pay attention to other reasons underneath of cognitive impairment including biological and societal particularity in female group.

Furthermore, several characteristics were also found to be predicting factors of cognitive impairment both

Table 2 Association of cognitive impairment and BMI among the oldest-old in China, CLHLS 2018

	Model 1 (no covariates)		Model 2 (covariates)	
Characteristics	OR (95%)	P value	OR (95%)	P value
BMI (reference=normal (18.5≤BMI<25))				
Underweight (BMI <18.5)	1.877 (1.688 to 2.086)	<0.001	1.296 (1.141 to 1.471)	<0.001
Overweight (25≤BMI≤30)	0.780 (0.683 to 0.890)	<0.001	1.045 (0.894 to 1.221)	0.582
Obesity (BMI >30)	0.933 (0.712 to 1.223)	0.617	1.057 (0.778 to 1.437)	0.722
Sociodemographics				
Age (reference=80–89)				
90–99			2.232 (1.976 to 2.520)	<0.001
100+			3.881 (3.343 to 4.507)	<0.001
Years of schooling (reference=0)				
1–6			0.552 (0.492 to 0.619)	<0.001
7+			0.258 (0.206 to 0.323)	<0.001
Single (couple)			1.258 (1.099 to 1.439)	0.001
Economic status (reference=very poor)				
Very rich			0.393 (0.224 to 0.692)	0.001
Rich			0.462 (0.285 to 0.749)	0.002
Average			0.707 (0.444 to 1.128)	0.146
Poor			0.953 (0.584 to 1.557)	0.848
Male (female)			0.697 (0.617 to 0.788)	<0.001
Health behaviour				
Smoking (seldom)			1.085 (0.920 to 1.281)	0.333
Drinking (no)			0.806 (0.680 to 0.955)	0.013
Physical activity (no)			0.716 (0.632 to 0.812)	<0.001
Health status				
Number of ADL disability (0)				
1–2			2.242 (1.963 to 2.560)	<0.001
3–4			4.662 (3.703 to 5.870)	<0.001
5–6			12.303 (9.075 to 16.678)	<0.001
Hypertension (no)			0.844 (0.754 to 0.945)	0.003
Diabetes (no)			0.956 (0.764 to 1.196)	0.691
Heart disease (no)			0.675 (0.576 to 0.791)	<0.001
Stroke (no)			1.182 (0.980 to 1.426)	0.081
Dyslipidaemia (no)			0.820 (0.601 to 1.119)	0.212
Cancer (no)			0.831 (0.487 to 1.418)	0.497

ADL, activity of daily living; BMI, body mass index; CLHLS, Chinese Longitudinal Healthy Longevity Survey.

in male and female oldest-old, such as age, education, economic status, physical activity, ADL disability, hypertension as well as heart disease. Consistent with other studies, age, ADL disability together with poor economic status were risk factors for cognitive impairment, whereas better education status and physical activity were significant protective factors against cognitive impairment.[3 10] Previous studies confirmed that age was significantly associated with a high risk of cognitive impairment.[47] Moreover, the economic status not only affects lifestyle, physical condition and nutritional status of older adults, but it is also related to the available social resources. In addition, our study showed that the relationship between economic status and cognitive impairment was not observed among males who were average or poor and females who were very rich, average or poor. We speculate that this may be due to the self-reported bias of economic status. As participants were asked about perceptions comparing to other people, answers may not reflect their actual economic situations, which may influence the findings. A more objective measurement for the wealth of older adults should be adopted in future researches. Furthermore,

Table 3 Association of BMI, sociodemographic, health behaviour and health status factors with cognitive impairment among male oldest-old in China, CLHLS 2018 (n=3837)

Variables	Model 1 (no covariates)	Model 2	Model 3	Model 4
BMI (reference=normal (18.5≤BMI<25))				
Underweight (BMI <18.5)	1.691 (1.410 to 2.027)***	1.427 (1.163 to 1.751)**	1.402 (1.141 to 1.724)**	1.466 (1.184 to 1.816)***
Overweight (25≤BMI≤30)	1.013 (0.824 to 1.245)	1.241 (0.993 to 1.552)#	1.253 (0.996 to 1.576)#	1.330 (1.041 to 1.699)*
Obesity (BMI >30)	1.271 (0.809 to 1.997)	1.525 (0.928 to 2.505)#	1.553 (0.934 to 2.584)#	1.439 (0.842 to 2.458)
Sociodemographics				
Age (reference=80–89)				
90–99		2.974 (2.483 to 3.562)***	2.860 (2.383 to 3.432)***	2.409 (1.986 to 2.922)***
100+		6.977 (5.503 to 8.846)***	6.505 (5.122 to 8.262)***	4.541 (3.505 to 5.883)***
Years of schooling (reference=0)				
1–6		0.457 (0.385 to 0.542)***	0.473 (0.397 to 0.562)***	0.492 (0.410 to 0.590)***
7+		0.267 (0.204 to 0.348)***	0.281 (0.214 to 0.368)***	0.225 (0.166 to 0.304)***
Single (couple)		1.288 (1.084 to 1.530)**	1.275 (1.071 to 1.517)**	1.185 (0.984 to 1.426)#
Economic status(reference=very poor)				
Very rich		0.293 (0.131 to 0.657)**	0.339 (0.149 to 0.770)*	0.271 (0.110 to 0.666)**
Rich		0.402 (0.202 to 0.802)*	0.463 (0.230 to 0.932)*	0.424 (0.194 to 0.924)*
Average		0.611 (0.313 to 1.193)	0.655 (0.333 to 1.288)	0.630 (0.296 to 1.342)
Poor		0.986 (0.484 to 2.006)	0.989 (0.483 to 2.027)	0.922 (0.416 to 2.044)
Health behaviour				
Smoking (seldom)			1.119 (0.922 to 1.358)	1.257 (1.029 to 1.536)*
Drinking (no)			0.701 (0.569 to 0.863)**	0.778 (0.627 to 0.965)*
Physical activity (no)			0.553 (0.460 to 0.666)***	0.708 (0.585 to 0.858)***
Health status				
Number of ADL disability (0)				
1–2				2.474 (1.992 to 3.072)***
3–4				5.453 (3.819 to 7.785)***
5–6				13.095 (8.065 to 21.261)***
Hypertension (no)				0.827 (0.684 to 0.999)*
Diabetes (no)				0.985 (0.675 to 1.437)
Heart disease (no)				0.757 (0.580 to 0.989)*
Stroke (no)				1.328 (1.009 to 1.748)*
Dyslipidaemia (no)				1.319 (0.784 to 2.220)
Cancer (no)				1.057 (0.418 to 2.674)
Nagelkerke R^2	0.013	0.245	0.263	0.349

#p<0.1, *p<0.05, **p<0.01, ***p<0.001.
ADL, activity of daily living; BMI, body mass index; CLHLS, Chinese Longitudinal Healthy Longevity Survey.

the status of ADL disability will reduce the circle of life among the oldest-old, increase negative emotions such as depression or anxiety, thus aggravating cognitive impairment.[50] In addition, our study found that physical activity was an independent and significant protective factor against cognitive impairment. The findings indicate that maintaining a high level of performance in ADLs, financial support and physical activity should be recommended to all of the oldest-old to achieve healthy ageing.

Similarly, not only does better education directly stimulate neurons in the cognitive domain, improve cognitive function, but it also increases awareness and opportunities to acquire health knowledge, improve health literacy and protect cognitive function.[51] Since it is difficult to improve the primary education level in a short term, it is vital to develop continuing education for seniors to prevent cognitive impairment. Furthermore, the older the subject is, the less likely for them to go to school. Therefore, informal education from family members and friends may be helpful for the oldest-old.

Interestingly, the study indicated that hypertension and heart disease did not increase the risk of cognitive impairment. The possible reason may be related to the increasing health awareness and health behaviours of the oldest-old with hypertension and heart disease in the process of coexisting with the disease for a long time.[52] According to the data of CLHLS (2018), the diagnosis and medication rate of hypertension among Chinese oldest-old is 95.8% and 84.7%. Meanwhile, the data about the diagnosis and medication compliance of heart disease

Table 4 Association of BMI, sociodemographic, health behaviour and health status factors with cognitive impairment among female oldest-old in China, CLHLS 2018 (n=5381)

Variables	Model 1 (no covariates)	Model 2	Model 3	Model 4
BMI (reference=normal (18.5≤BMI<25))				
Underweight (BMI <18.5)	1.776 (1.550 to 2.035)***	1.349 (1.161 to 1.567)***	1.332 (1.145 to 1.548)***	1.217 (1.039 to 1.425)*
Overweight (25≤BMI≤30)	0.660 (0.553 to 0.786)***	0.857 (0.707 to 1.038)	0.866 (0.714 to 1.050)	0.889 (0.728 to 1.086)
Obesity (BMI >30)	0.723 (0.515 to 1.016)#	0.937 (0.665 to 1.320)	0.937 (0.664 to 1.321)	0.881 (0.612 to 1.267)
Sociodemographics				
Age (reference=80–89)				
90–99		2.801 (2.411 to 3.253)***	2.682 (2.306 to 3.118)***	2.139 (1.826 to 2.507)***
100+		6.333 (5.356 to 7.489)***	5.855 (4.942 to 6.936)***	3.606 (3.000 to 4.336)***
Years of schooling (reference=0)			0	0
1–6		0.586 (0.509 to 0.675)***	0.585 (0.508 to 0.675)***	0.597 (0.515 to 0.693)***
7+		0.296 (0.212 to 0.414)***	0.307 (0.220 to 0.430)***	0.284 (0.198 to 0.408)***
Single (couple)		1.305 (1.069 to 1.592)**	1.340 (1.097 to 1.637)**	1.332 (1.085 to 1.635)**
Economic status(reference=very poor)				
Very rich		0.399 (0.201 to 0.794)**	0.475 (0.239 to 0.945)*	0.510 (0.244 to1.064)#
Rich		0.393 (0.224 to 0.691)**	0.435 (0.246 to 0.772)**	0.465 (0.252 to 0.859)*
Average		0.661 (0.385 to 1.137)	0.706 (0.407 to 1.225)	0.735 (0.407 to 1.327)
Poor		0.859 (0.485 to 1.520)	0.900 (0.504 to 1.607)	0.925 (0.497 to 1.720)
Health behaviour				
Smoking (seldom)			0.801 (0.593 to 1.082)	0.803 (0.587 to 1.098)
Drinking (no)			0.785 (0.595 to 1.037)#	0.852 (0.639 to 1.137)
Physical activity (no)			0.607 (0.516 to 0.714)***	0.731 (0.618 to 0.864)***
Health status				
Number of ADL disability (0)				
1–2				2.145 (1.813 to 2.537)***
3–4				4.227 (3.137 to 5.696)***
5–6				11.834 (8.021 to 17.459)***
Hypertension (no)				0.856 (0.744 to 0.985)*
Diabetes (no)				0.957 (0.725 to 1.264)
Heart disease (no)				0.637 (0.525 to 0.774)***
Stroke (no)				1.076 (0.836 to 1.386)
Dyslipidaemia (no)				0.614 (0.422 to 0.896)
Cancer (no)				0.751 (0.380 to 1.482)
Nagelkerke R^2	0.033	0.246	0.256	0.336

#p<0.1, *p<0.05, **p<0.01, ***p<0.001.
BMI, body mass index; CLHLS, Chinese Longitudinal Healthy Longevity Survey.

among Chinese oldest-old are 94.3% and 79.7%, respectively. Additionally, it is reported that the usage of statins in the treatment of heart disease may reduce the prevalence of cognitive impairment.[53] The finding demonstrates that we should pay attention to timely diagnosis and treatment of hypertension and heart disease.

In addition, stroke is significantly associated with a high risk of cognitive impairment among male seniors (80+), which was in agreement with previous studies.[54 55] Due to the physiological differences between males and females, there are gender differences from the clinical aspect to the molecular aspect after stroke. Furthermore, different stroke mechanisms may lead to differences in cognitive dysfunction between the two subgroups.[56] Furthermore, smoking maybe a risk factor cognitive impairment while drinking maybe a protective factor for male oldest-old, which deserves further research.

The findings indicated the importance of weight management of oldest-old by gender. Government should detect and strength health management of high/low BMI in male oldest-old and low BMI in females. On one hand, we suggest improving awareness of healthy weight through basic public health service. On the other hand, it is advisable to build information management system to monitoring BMI and cognitive function among the community-dwelling oldest-old in China.

However, this study has some limitations. First, only correlation rather than causal relationships could be identified through cross-sectional design. Thus, longitudinal studies are required to investigate the

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cause-and-effect relationship. Second, waist circumference was not adopted to evaluate the status of obesity, we should add the indicator in the future. Thirdly, some self-reported information may lead to the possibility of bias.

CONCLUSION

The correlation between BMI and cognitive impairment differed between male and female oldest-old. Overweight/underweight are red flags for cognitive impairment among males. However, underweight females are more likely to have cognitive impairment. Moreover, age, years of schooling, economic status, physical activity, ADL disability, hypertension and heart disease are also predictors for cognitive impairment in both male and female oldest-old. According to the findings, the government should pay attention to different BMI groups and adopt precise prevention strategies based on gender. Furthermore, appropriate physical activities, more educational opportunities, timely diagnoses and treatments of hypertension and heart disease should be recommended to all oldest-old. In summary, the findings of this study will be helpful for more precise prevention of cognitive impairment based on gender worldwide among oldest-old, especially for developing countries.

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Patient consent for publication Consent obtained from parent(s)/guardian(s).

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