ORIGINAL RESEARCH

Associations between obesity and cognitive impairment in the Chinese elderly: an observational study

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Purpose: The aim of this study was to investigate the relationship between obesity and cognitive impairment in the Chinese elderly.

Patients and methods: Patients aged 60 years or above were enrolled from the Department of Geriatrics of The First Affiliated Hospital of Chongqing Medical University from March 2013 to May 2017. Mini-Mental State Examination scale was used to assess the cognitive function. Body mass index (BMI) and waist–hip ratio were used to classify obesity. Student's t-test, Mann–Whitney U-test, or chi-squared test was used to compare the data between participants with normal cognition and participants with cognitive impairment as appropriate. Univariate logistic regression models and multivariate logistic regression models were performed to explore the relationship between BMI or abdominal obesity and cognitive impairment.

Results: A total of 1,100 patients including 568 men and 532 women aged 60–98 years (median age 79 years) were enrolled. After adjusting for age, gender, smoking, drinking, education level, hypercholesterolemia, hypertension, and diabetes, overweight was significantly associated with a decreased risk of cognitive impairment (OR=0.458, 95% CI=0.298–0.703, $P<0.001$). After adjustment for age, education level, hypercholesterolemia, hypertension, and diabetes, abdominal obesity remained significantly associated with an increased risk of cognitive impairment (OR=1.532, 95% CI=1.037–2.263, $P=0.032$).

Conclusion: Overweight is associated with a decreased risk of cognitive impairment in the Chinese elderly, while abdominal obesity is associated with an increased risk of cognitive impairment independent of conventional sociodemographic, lifestyle, and health-related comorbid factors.

Keywords: body mass index, cognitive function, elderly, waist-hip ratio

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Introduction

Aging of the population has become a public health problem following the rapid development of economy. Aging and age-related diseases have brought a huge economic burden to the whole society. Cognitive impairment and dementia are a kind of common age-related diseases. Epidemiological data show that dementia affects 5%–10% of people aged 65 years or older in higher-income countries. And the prevalence doubles every 5 years of age after age 65. The annual age-specific incidences of dementia range from 0.1% at age 60–64 to 8.6% at age 95.[1] Cognitive impairment and dementia have become a major challenge to health and social care resources. Currently there is limited success on the treatment of cognitive impairment and dementia despite therapeutic advances. Therefore, the prevention is extremely important. Recent research suggests that preventing the risk factors of dementia is expected to reduce the risk ratio by 35%.[2] Thus, identifying the potential risk factors of cognitive impairment

and dementia, especially those modifiable risk factors, is an effective way to prevent cognitive decline.

Overweight and obesity have become a global epidemic, even among the elderly. According to the 2014 National Physique Monitoring Report, the prevalence rates of overweight and obesity in the Chinese elderly are 41.6% and 13.9% in 2014, which are 1.8% and 0.9% higher than those in 2010, respectively.[3] There is a growing body of researches investigating the relationship between obesity and cognitive impairment nowadays, but the results are conflicting mainly because of the different study populations.[4–9] Meanwhile, there are limited data on the relationship between obesity and cognitive impairment independent of other metabolic risk factors in the elderly in People's Republic of China. Therefore, we conducted this study to investigate the relationship between obesity and cognitive impairment in the Chinese elderly by using comprehensive geriatric assessment data.

Participants and methods
Participants and data collection

Patients aged 60 years or above were recruited from the Department of Geriatrics of The First Affiliated Hospital of Chongqing Medical University from March 2013 to May 2017. Patients with Parkinson's disease, intracranial tumor, severe psychosis, stroke, severe sensory damage, and severe complications were excluded. We also excluded patients involved in other studies. All the participants underwent a comprehensive geriatric assessment conducted by a trained nurse and confirmed by an experienced doctor. Data including social demographic characteristics, personal and family history, physical examination, laboratory tests, and cognitive function assessment were collected. Smoking was defined as having smoked at least one cigarette for over 6 months. Drinking was defined as having drunk more than once a week for at least 6 months. Height, weight, waist circumference, and hip circumference were manually measured. Body mass index (BMI) was calculated by the equation: BMI = weight (kg)/height (m).[2] Waist–hip ratio (WHR) was calculated by the equation: WHR = waist circumference (cm)/hip circumference (cm). Hypertension was defined as a systolic blood pressure higher than 140 mmHg and/or a diastolic blood pressure higher than 90 mmHg or taking antihypertensive drugs. Diabetes was defined according to the revised 1999 WHO criteria: fasting plasma glucose level ≥126 mg/dL (7.0 mmol/L) and plasma glucose level ≥200 mg/dL (11.1 mmol/L) 2 hours after a 75 g oral glucose load. Participants taking antidiabetic medications were also recognized as diabetic patients. Hypercholesterolemia was defined as total

cholesterol >5.72 mmol/L or taking lipid-lowering drugs. All procedures performed in this study involving human participants were in accordance with the basic principles of the Declaration of Helsinki and had been approved by the Ethics Committee of The First Affiliated Hospital of Chongqing Medical University (Approved in 2012, No 15). No informed consent was available due to the retrospective design.

Cognitive function assessment and obesity definition

Mini-Mental State Examination (MMSE) scale was used to assess the cognitive function. The scores of MMSE range from 0 to 30, and higher scores indicate better cognitive function. Cognitive impairment was defined as a score ≤17 for illiterates, ≤20 for patients with primary school education, and ≤24 for those with junior high school degree or above.[10] BMI and WHR were used to classify obesity. BMI was classified into the following four categories: <18.5 kg/m² (underweight), 18.5–23.9 kg/m² (normal weight), 24.0–27.9 kg/m² (overweight), and ≥28.0 kg/m² (obesity). Abdominal obesity was defined as follows: WHR ≥0.9 for males and ≥0.85 for females.[11]

Statistical analysis

All the statistical analyses were performed by SPSS 19.0 (IBM Corporation, SPPS Inc, Chicago, IL, USA). The Kolmogorov–Smirnov test was used to determine the normality of distributions. Continuous variables were presented as mean ± SD or percentiles, while categorical variables were presented as percentages. Student's t-test, Mann–Whitney U-test, or chi-squared test was used to compare the data between participants with normal cognition and participants with cognitive impairment as appropriate. Univariate logistic regression models and multivariate logistic regression models were performed to explore the relationship between BMI or abdominal obesity and cognitive impairment. The results were considered significant when $P<0.05$.

Results
Baseline characteristics

A total of 1,100 elderly people including 568 men and 532 women aged 60–98 years (median age 79 years) were enrolled in this study. One hundred and eighty-five (16.8%) people were diagnosed with cognitive impairment. The mean BMI was 23.23±3.65 kg/m² and the median WHR was 0.82 (0.78, 0.86). A total of 105 (9.5%) participants were classified as obese and 206 (18.7%) participants were classified as abdominal obese. The numbers of patients diagnosed

with diabetes, hypertension, and hypercholesterolemia were 325 (29.5%), 383 (34.8%), and 79 (7.2%), respectively. Baseline characteristics of participants are presented in Table 1.

Characteristics between participants with normal cognition and participants with cognitive impairment

The characteristics between participants with normal cognition and participants with cognitive impairment are displayed in Table 2. The median score of MMSE scale in the cognitive impairment group was much lower than that in the normal cognition group (13 vs 27, $P<0.001$). The median age of participants with cognitive impairment was significantly older than that of participants with normal cognition (82 vs 78 years, $P<0.001$). The mean BMI in the cognitive impairment group was relatively lower than that in the normal cognition group (22.43 vs 23.40 kg/m^2, $P=0.001$). And the BMI categories were significantly different between groups. Although there were no significant differences in the waist and WHR between the two groups, the proportion of participants with abdominal obesity in the cognitive

impairment group was significantly greater than that in the normal cognition group (25.4% vs 17.4%, $P=0.011$).

Relationship between BMI and cognitive impairment

Univariate logistic regression analysis showed that overweight (BMI=24.0–27.9 kg/m^2) was significantly associated with a lower risk of cognitive impairment (OR=0.439, 95% CI=0.291–0.664, $P<0.001$). And this association remained significant after adjusting for some conventional risk factors. As demonstrated in Table 3, overweight remained significantly associated with a lower risk of cognitive impairment after adjusting for age, gender, smoking, drinking, education level, hypercholesterolemia, hypertension, and diabetes (OR=0.458, 95% CI=0.298–0.703, $P<0.001$). While underweight (BMI <18.5 kg/m^2) and obesity (BMI ≥28.0 kg/m^2) were not significantly associated with cognitive impairment (both $P>0.1$) when using normal weight (BMI=18.5–23.9 kg/m^2) as the reference.

Relationship between abdominal obesity and cognitive impairment

The association between abdominal obesity and cognitive impairment is shown in Table 4. In the univariate logistic regression model, abdominal obesity (defined by WHR cutoffs) was significantly associated with a higher risk of cognitive impairment (OR=1.619, 95% CI=1.116–2.350, $P=0.011$). In the multivariate logistic model, abdominal obesity remained significantly associated with a higher risk of cognitive impairment after adjusting for lifestyle risk factors including drinking and smoking (OR=1.619, 95% CI=1.113–2.354, $P=0.012$). Similarly, abdominal obesity was significantly associated with a higher risk of cognitive impairment independent of other metabolic diseases such as hypercholesterolemia, hypertension, and diabetes (OR=1.667, 95% CI=1.139–2.438, $P=0.008$). Even after adjustment for age, education level, hypercholesterolemia, hypertension, and diabetes, abdominal obesity remained significantly associated with an increased risk of cognitive impairment (OR=1.532, 95% CI=1.037–2.263, $P=0.032$).

Discussion

The relationship between obesity and cognitive impairment has been a controversial subject for many years. The present study demonstrated that overweight defined by BMI categories was significantly associated with a lower risk of cognitive impairment, while abdominal obesity defined by WHR cutoffs was significantly associated with a higher risk

Table 1 Baseline characteristics of participants

Characteristics	Mean ± SD or P50 (P25, P75) or number (percentage)
Age (years)	79 (73, 83)
Male, n (%)	568 (51.6)
Education level, n (%)	
Middle school and above	292 (26.5)
Primary school	384 (34.9)
Illiteracy	424 (38.5)
BMI (kg/m^2)	23.23±3.65
BMI category (kg/m^2), n (%)	
18.5–23.9	575 (52.2)
<18.5	93 (8.4)
24.0–27.9	327 (29.7)
≥28.0	105 (9.5)
Waist (cm)	73 (67, 81)
Waist–hip ratio	0.82 (0.78, 0.86)
Abdominal obesity, n (%)	206 (18.7)
Smoking, n (%)	278 (25.2)
Drinking, n (%)	207 (18.8)
Diabetes, n (%)	325 (29.5)
Hypertension, n (%)	383 (34.8)
Hypercholesterolemia, n (%)	79 (7.2)
Cognitive impairment, n (%)	185 (16.8)
MMSE score	26 (23, 28)

Abbreviations: BMI, body mass index; MMSE, Mini-Mental State Examination.

Table 2 Characteristics between participants with normal cognition and participants with cognitive impairment

Variables	Normal cognition (N=915)	Cognitive impairment (N=185)	P-value
Age (years)	78.00 (72.00, 83.00)	82.00 (77.50, 85.50)	<0.001
Male, n (%)	480 (52.5)	88 (47.6)	0.225
Education level, n (%)			0.051
Middle school and above	244 (26.7)	48 (25.9)	
Primary school	306 (33.4)	78 (42.2)	
Illiteracy	365 (39.9)	59 (31.9)	
BMI (kg/m^2)	23.40±3.64	22.43±3.56	0.001
BMI category (kg/m^2), n (%)			0.001
18.5–23.9	458 (50.1)	117 (63.2)	
<18.5	74 (8.1)	19 (10.3)	
24.0–27.9	294 (32.1)	33 (17.8)	
≥28.0	89 (9.7)	16 (8.6)	
Waist (cm)	73.00 (67.00, 81.00)	72.00 (65.00, 79.50)	0.071
Waist–hip ratio	0.82 (0.78, 0.85)	0.82 (0.78, 0.86)	0.092
Abdominal obesity, n (%)	159 (17.4)	47 (25.4)	0.011
Smoking, n (%)	233 (25.5)	45 (24.3)	0.745
Drinking, n (%)	182 (19.9)	25 (13.5)	0.043
TC (mmol/L)	4.18±1.09	4.19±1.11	0.915
TG (mmol/L)	1.18 (0.85, 1.61)	1.12 (0.83, 1.58)	0.302
LDL-C (mmol/L)	2.49±0.91	2.43±0.96	0.392
HDL-C (mmol/L)	1.33 (1.08, 1.62)	1.36 (1.04, 1.63)	0.979
Hypercholesterolemia, n (%)	61 (6.7)	18 (9.7)	0.141
Hypertension, n (%)	307 (33.6)	76 (41.1)	0.050
Diabetes, n (%)	265 (29.0)	60 (32.4)	0.345
MMSE score	27 (25, 28)	13 (9, 16)	<0.001

Note: Data are shown as mean ± SD or P50 (P25, P75) or number (percentage).
Abbreviations: BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MMSE, Mini-Mental State Examination; TC, total cholesterol; TG, triglyceride.

of cognitive impairment in the Chinese elderly even after adjusting for sociodemographic, lifestyle, and health-related comorbid factors.

Our findings are consistent with several previous studies, which reported that overweight in late life was associated with a reduced risk of dementia. Atti et al investigated the relationship between late-life BMI and dementia incidence in 1,255 subjects aged 75 years and older in their 9-year follow-up study and revealed that subjects who were overweight (BMI ≥25.0 kg/m^2) had a lower risk of developing dementia than subjects with normal weight (BMI=20.0–24.9 kg/m^2) (HR=0.75, 95% CI=0.59–0.96).[12] This study also showed that there was no difference in the risk of dementia between subjects with obesity and subjects with normal weight. Ghaderpanahi et al explored the association between BMI and the risk of dementia in 108 participants aged 80 years and older in a cross-sectional study and showed that overweight (BMI=25.0–29.9 kg/m^2) was an independent and significant

protective factor against dementia risk (OR=0.24, 95% CI=0.06–0.93).[13] On the other hand, some studies revealed that midlife overweight and obesity were associated with a higher risk of dementia.[14] The potential mechanisms linking overweight and cognitive impairment are not entirely clear. Two possible mechanisms might explain the beneficial role of overweight on cognitive impairment in late life. First, the hormone leptin, which is mainly secreted by the adipose tissue, might play a role as a cognitive enhancer. By regulating hippocampal synaptic plasticity and amyloid β-processing, leptin has been found to improve learning and memory performance in rodents.[15,16] Second, individuals who are overweight have a lower mortality risk than individuals who are underweight or with normal weight in the elderly. Thus, it seems that overweight is indicative of a better health status compared with normal weight or underweight in late life.[17] While the increased risk of cognitive impairment in subjects with midlife overweight and obesity could be explained by the

Table 3 Association of body mass index with cognitive impairment

Adjustment	OR	95% CI	P-value
Model 1 (kg/m²)			
18.5–23.9	1		
<18.5	1.005	0.584–1.731	0.985
24.0–27.9	0.439	0.291–0.664	<0.001
≥28.0	0.704	0.398–1.244	0.227
Model 2 (kg/m²)			
18.5–23.9	1		
<18.5	0.877	0.501–1.535	0.645
24.0–27.9	0.450	0.296–0.685	<0.001
≥28.0	0.740	0.414–1.321	0.308
Model 3 (kg/m²)			
18.5–23.9	1		
<18.5	0.857	0.486–1.510	0.592
24.0–27.9	0.458	0.300–0.698	<0.001
≥28.0	0.708	0.394–1.270	0.247
Model 4 (kg/m²)			
18.5–23.9	1		
<18.5	1.033	0.595–1.793	0.907
24.0–27.9	0.439	0.289–0.667	<0.001
≥28.0	0.732	0.412–1.301	0.288
Model 5 (kg/m²)			
18.5–23.9	1		
<18.5	0.876	0.493–1.556	0.651
24.0–27.9	0.458	0.298–0.703	<0.001
≥28.0	0.758	0.419–1.370	0.359

Notes: Model 1: no adjustment; model 2: adjust for age, gender; model 3: adjust for age, gender, drinking, smoking, education level; model 4: adjust for hypercholesterolemia, hypertension, diabetes; model 5: adjust for age, gender, smoking, drinking, education level, hypercholesterolemia, hypertension, diabetes.

fact that a higher BMI in midlife is usually associated with cardiovascular and metabolic risk factors which are related to an increased risk of cognitive impairment.[18,19]

Another finding of the present study is that abdominal obesity is associated with an increased risk of cognitive impairment. Liu et al showed that central obesity (defined by WHR <0.9 for males and <0.85 for females) was significantly associated with a higher risk of cognitive impairment in 491 subjects aged 70 years and older (OR=1.980, 95% CI=1.129–3.472).[20] Luchsinger et al revealed that a higher WHR was related to a higher risk of late-onset Alzheimer's disease (HR of the fourth quartile compared to the first=2.5, 95% CI=1.3–4.7) after adjustment for conventional risk factors.[21] Abdominal obesity is a typical characteristic of the body fat distribution among the Chinese population. Individuals with abdominal obesity usually have a higher body fat percentage than individuals with simple obesity.[22,23] Abdominal obesity is a component of metabolic syndrome, which also includes insulin resistance, hyperglycemia, dyslipidemia, and hypertension.[24] Our results suggested that abdominal obesity was a risk factor of cognitive impairment independent of hypercholesterolemia, hypertension, and diabetes. The underlying mechanism may partly be explained by insulin resistance. Recent studies have shown that insulin has the ability to regulate neural metabolism and trigger glucose uptake in the hippocampus and medial temporal lobe. By binding to insulin receptors, insulin plays an important part in hippocampal memory processing. Thus, insulin resistance in the hippocampus could impair spatial learning and synaptic plasticity.[25,26]

Another explanation is vascular endothelial damage and brain dysfunction. It has been proved that every component of metabolic syndrome is independently associated with vascular endothelial damage and thereby limits cerebrovascular blood flow. As a result, the risk of cognitive impairment increases, especially the risk of vascular cognitive impairment.[27]

In the present study, no significant association was found between underweight and cognitive impairment, which was in contrast to previous studies that revealed a significant association between underweight and an increased risk of dementia.[28] One possible explanation for this inconsistency may be that elderly people who are underweight have a higher risk of death and thus cognitive impairment is probably underestimated. So we could not rule out the possibility that the lack of association between a low BMI and an increased risk of cognitive impairment in the present study is due

Table 4 Association of abdominal obesity with cognitive impairment

Adjustment	OR	95% CI	P-value
No adjustment	1.619	1.116–2.350	0.011
Adjust for drinking, smoking	1.619	1.113–2.354	0.012
Adjust for age, education level	1.473	1.006–2.156	0.046
Adjust for hypercholesterolemia, hypertension, diabetes	1.667	1.139–2.438	0.008
Adjust for age, education level, hypercholesterolemia, hypertension, diabetes	1.532	1.037–2.263	0.032

to the underestimation of cognitive impairment incidence among the dead.

This study may have several potential limitations. First, this is a cross-sectional study. Only correlations rather than causal relationships can be established due to the study design. Although we adjusted some conventional sociodemographic, lifestyle, and health-related comorbid factors, we cannot adjust the other unmeasured confounding factors such as APOE4 genotype, diet, and drugs. Second, this is a single-center study and all the participants are from the same tertiary hospital in southwest China, so we may not generalize the results to other demographic groups. Third, the association between obesity and different types of cognitive impairment such as vascular cognitive impairment and Alzheimer's disease is not explored due to insufficient data in this study. Further multicentered, prospective cohort studies enrolled participants with different demographic characteristics are needed.

Conclusion

Overweight based on BMI categories is associated with a lower risk of cognitive impairment in the Chinese elderly, while abdominal obesity defined by WHR cutoffs is associated with a higher risk of cognitive impairment independent of conventional sociodemographic, lifestyle, and health-related comorbid factors. The results of this study are of value for the prevention of cognitive impairment. Further multicentered, prospective cohort studies with a long-term follow-up are needed.

Acknowledgments

Disclosure

The authors report no conflicts of interest in this work.

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