Associations of Body Mass Index, Visceral Fat Area, Waist Circumference, and Waist-To-Hip Ratio with Cognitive Function in Western China: Results from A WCHAT Study

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Abstract

Objectives

This study examined the relationship between cognitive performance and obesity parameters, such as body mass index (BMI), visceral fat area (VFA), waist circumference (WC), and waist-to-hip ratio (WHR) in western China.

Study design

A cross-sectional study

Methods

3914 participants, aged >50 years, were recruited in this study. Anthropometrics measurements, life-style factors, chronic disease comorbidities, and sleep qualities were recorded for each participant. Among the anthropometrics, BMI, WC, and WHR were assessed using standard procedures, while VFA was calculated using bioelectrical impedance analysis. Cognitive performance was estimated using the Short Portable Mental Status Questionnaire (SPMSQ). Finally, relationships between cognitive abilities and BMI, VFA, WC, and WHR were evaluated using univariate and multivariate regression analyses.

Results

Cognitive decline (CD) occurred at a rate of 13.29% among the 3914 participants. A strong correlation was observed between cognitive abilities and BMI of male patients aged 50-59 yrs (OR 1.116, 95% CI 1.002-1.242), in the adjusted model. Alternately, WHR was shown to be significantly related to CD in females aged >70 years (OR 0.041, 95% CI 0.002-0.671). WC was shown to have a strong association with CD in males (OR 1.023, 95% CI 1.003-1.024). Lastly, WHR was closely connected to CD in participants with BMI < 25 kg/m² (OR 0.022, 95% CI 0.002-0.209).

Conclusions

Our findings suggest that a higher middle age BMI is associated with CD, whereas, in the elderly population, a higher WHR is related to improved cognitive performance. Further investigation is warranted to elucidate a relationship between VFA and CD.

Background

Obesity, or excessive body fat, is one of the leading disease conditions in the world today. Several studies have demonstrated a positive association between obesity and dementia or cognitive decline (CD). However, the impact of obesity markers, such as body mass index (BMI), visceral fat area (VFA), waist circumference (WC) and waist-to-hip ratio (WHR), in patients without dementia remains unclear. Among the obesity markers, BMI is considered the most common risk factor for dementia. However, the evidences for this are controversial. Several studies have suggested that a higher middle age BMI can significantly increase the risk for dementia^{1,2}. Conversely, in another study, BMI was discovered to have a U-shaped relationship with dementia. Therefore, in patients < 76 year old, a high BMI increased dementia risk, whereas, in patients > 76 year old, high BMI reduced dementia risk³. Moreover, several longitudinal studies demonstrated that in adulthood, excessive body fat augmented risk of CD later in life⁴⁻⁶.

The evidences concerning the relationship between VFA and cognitive abilities are also conflicting. In one study, increased visceral adiposity was associated with poor cognitive performance in subjects < 70 year old⁷. Likewise, in

another study, excessive VFA was shown to worse cognitive abilities in young adults⁸. Conversely, a recent study demonstrated that a high VFA is closely correlated with a low risk of non-amnesic mild cognitive impairment (MCI) in women, suggesting visceral fat may partially protect against CD⁹. Alternately, in a study of type 2 diabetes (T2D) patients, it was proposed that the impaired endothelium-independent vascular smooth muscle reactivity may mediate the relationship between elevated visceral adiposity and reduced cognitive performance¹⁰.

In terms of WHR, researchers discovered an association with cognitive impairment, which may be a result of neurodegenerative, vascular, or metabolic processes that modulate brain structures¹¹. Likewise, a longitudinal study demonstrated that both WHR and WC can predict a nearly two-fold decrease in cognitive performance in T2D participants within 2 yrs¹². Conversely, in another report, WHR was shown to be related to slower cognitive decline in elderly patients, indicating cognitive protection associated with higher WHR in the elderly¹³.

In this study, we collected cross-sectional data from the West-China Health and Aging Trend (WCHAT) study, involving a multi-ethnic cohort study in western China, to assess the relationship between adiposity parameters (such as, BMI, VFA, WHR, and WC) and CD.

Methods

This cross-sectional study collected data from the WCHAT study, which examined the relationship between geriatrics syndromes and lifestyle of people in western China, such as diet, alcohol consumption, and smoking, and so on¹⁴⁻¹⁶. The WCHAT study received approval from the Ethical Review Committee (reference: 2017-445) in the West China Hospital, Sichuan University, Chengdu, China. 4 independent interviewers were involved in data assembly from 4 western China provinces, namely, Yunnan, Guizhou, Sichuan, and Xinjiang.

Study participants

The study participants, aged >50 yr old, were selected by the local government and provided verbal and written consent to their participation in the study. The WCHAT study, which provided us the data for this study, included 7,536 participants aged ≥ 50 yr old from over 18 ethnic populations among 4 western China provinces; Sichuan, Yunnan, Guizhou, and Xinjiang. Among them, 4,500 participants with bioimpedance data, measured using Inbody770, were selected for the study. Among these participants, those with stroke (62), mental illness (5), participants missing cognitive function assessment (239), and participants belonging to a small ethnic group (280) were excluded from the study, resulting in a total of 3,914 participants included in this study.

Demographic, anthropometric, and life styles data collection

The baseline demographic information included age, gender, marital status, educational level, ethnic background, occupation, fertility condition, and hearing ability. The lifestyle variables included tea-drinking, alcohol drinking, smoking, and sleep quality. The anthropometric data included height, weight, BMI, WC, WHR, and VFA. WHR was measured twice by volunteers and the average data was used in the analysis. To calculate WC, measurement was taken at the midpoint between the iliac crest and lower rib at the end of a normal expiration. The hip circumference was measured at the maximum circumference over the buttocks below the iliac crest. WHR was calculated as the ratio of WC to hip circumference. Weight measurement was performed using a digital scale and height was calculated using a stadiometer. The BMI was calculated as the weight over height squared. VFA was assessed using bioimpedance analysis with the help of Inbody 770 (BioSpace, Seoul, Korea)¹⁷⁻¹⁹.

Assessment of cognitive decline, depression, sleep quality, and chronic diseases.

Cognitive performance was assessed according to the questions on the Short Portable Mental Status Questionnaire (SPMSQ). A high SPMSQ score denoted poor cognitive ability. In particular, a score of 0-2 represented good cognitive performance, a score of 3-4 indicated MCI, a score of 5-7 meant moderate cognitive impairment, and lastly, a score of 8-10 indicated severe cognitive impairment or CD²⁰. In addition, depression was evaluated using a 15 question Geriatric Depression Scale (GDS-15)²¹ with yes/no answers. The GDS-15 is a universally used questionnaire for the detection of depression. Sleep quality was evaluated using the widely used sleep assessment tool, Pittsburgh Sleep Quality Index (PSQI), where scores >5 were indicative of poor self-reported sleep quality²². Lastly, a self-reported medical history of chronic diseases was taken from each participant. Chronic diseases included hypertension, osteoarticular disease, lung disease, diabetes mellitus, and so on and comorbidities was defined as having two or more chronic diseases.

Statistical analysis

The obesity threshold was set as follows: BMI $\geq 25.0 \text{ kg/m}^2$ (World Health Organization)²³, WHR: 0.90 in men and 0.85 in women (Asian modified WHO criteria for metabolic syndrome)²⁴, WC >90 cm for men and >80 cm for women (Asian modified The National Cholesterol Education Program)²⁴, VFA $\geq 100 \text{ cm}^2$ (published literature)²⁵⁻²⁷.

The normality of variables was assessed using R version 3.6.1. The participants were assigned to one of two groups: complete cognitive function (CCF) or CD. Our findings are expressed as mean $\pm$ standard deviation (SD). Statistical significance ($p < 0.05$, two sided) was assessed with student's *t*-test (comparing 2 different groups) and the count data is represented as a percentage, using the χ^2 test.

As this study explored the associations between cognitive performance and obesity variables like BMI, VFA, WC, and WHR, we established both univariate and multivariate regression models with BMI, VFA, WC, and WHR as the independent variables and cognitive performance as the dependent variable. The multivariate models were next adjusted according to BMI, VFA, WC, and WHR to produce fully adjusted cognitive results.

Results

Characteristics of the study participants

3,914 participants, aged ≥ 50 yrs were included in this study. The incidence of CD among the selected participants was 13.29%. A breakdown of their age groups showed that < 60, 60–69, 70–79 and ≥ 80 had a CD prevalence of 10.23%, 11.79%, 20.65%, and 33.03%, respectively, suggesting an increase in CD with age. Among the different ethnic populations, CD was distributed as follows: Han, Zang, and Qiang exhibited 9.52%, 17.66%, and 15.25% of CD respectively. A summary of data, including the clinical and sociodemographic, anthropometric, sleeping quality, lifestyle factors, depression, and chronic diseases comorbidity are provided in Table 1. Based on our analysis, participants with CD were, on average, older females who were missing a significant other, were of low educational background, worked as laborer, drank less tea and alcohol, smoked less, had multiple children, had impaired hearing, high GDS-15 score, high WC, and low WHR, as compared to participants without CD (Table 1). We also demonstrated that sleep quality and chronic disease comorbidities had a negative effect on CD. However, VFA and BMI were not significantly altered between the CCF and the CD groups (Table 1).

Table 1
Basic characteristics of study participates (n = 3914).

	Complete cognitive function	Cognitive decline	P value
	N = 3394 (86.71%)	N = 520 (13.29%)	
Ethnic groups			< .0.01
Han	1635(90.48%)	172(9.52%)	
Zang	909(82.34%)	195(17.66%)	
Qiang	850(84.75%)	153(15.25%)	
Age groups			< .0.01
<60	1421(89.77%)	162(10.23%)	
60–69	1377(88.21%)	184(11.79%)	
70–79	515(79.35%)	134(20.65%)	
≥ 80	81(66.94%)	40(33.03%)	
Gender			< .0.01
male	1298(91.93%)	114(8.07%)	
female	2096(83.77%)	406(16.23%)	
Marriage status			< .0.01
With spouse	2905(88.08%)	393(11.92%)	
Without spouse	489(79.38%)	127(20.62%)	
Smoking history			<0.01
Yes	610(92.71%)	48(7.29%)	
No	2784(85.51%)	472(14.49%)	
Drinking history			< .0.01
Yes	890(90.17%)	97(9.83%)	
No	2504(85.55%)	423(14.45%)	
Tea drinking			< .0.01
Yes	1713(88.44%)	224(11.56%)	
No	1681(85.03%)	296(14.97%)	
Education level			< .0.01
Primary school and below	2054(83.06%)	419(16.94%)	
Middle school and above	1340(92.99%)	101(7.01%)	

Data are shown using % or mean (standard deviation). P values were calculated with chi-squared tests and one-way analysis of variance (ANOVA) for categorical and continuous variables, respectively. BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.

	Complete cognitive function	Cognitive decline	P value
Occupation			< .0.01
Physical labor	2885(85.63%)	484(14.37%)	
Brain work	509(93.39%)	36(6.61%)	
Fertility status			< .0.01
Yes	2077(84.06%)	394(15.94%)	
No	1317(91.27%)	126(8.73%)	
Chronic disease comorbidity			0.108
Yes	376(84.11%)	71(15.89%)	
No	3018(87.05%)	449(12.95%)	
Hearing ability			<0.01
Complete	2696(88.98%)	334(11.02%)	
Impaired	698(78.96%)	186(21.04%)	
Sleeping quality			0.123
Good	1666(86.05%)	270(13.95%)	
Bad	1563(87.76%)	218(12.24%	
WC	87.22 ± 10.72	88.31 ± 11.24	0.035
M≤90,F≤80	2490(87.15%)	367(12.85)	<0.01
M ≤ 90,F ≤ 80	904(85.53%)	153(14.47%)	
WHR	0.92 ± 0.08	0.90 ± 0.09	
M ≥ 0.9,F ≥ 0.85	2490(87.15%)	367(12.85%)	0.193
M<0.9,F<0.85	904(85.53%)	153(14.47%)	0.089
VFA	107.45 ± 40.42	111.01 ± 44.94	
≥ 100	1841(86.23%)	294(13.77%)	
<100	1553(87.30%)	226(12.70%)	0.326
BMI	25.38 ± 3.68	25.52 ± 4.67	
BMI<18.5	62(82.67%)	13(17.33%)	
18.5 ≤ BMI<25	1538(86.65%)	237(13.35%)	0.684
25 ≤ BMI	1722(86.66%)	265(13.34%)	
GDS-15 score	2.45 ± 2.23	3.73 ± 2.72	
Data are shown using % or mean (standard deviation). P values were calculated with chi-squared tests and one-way analysis of variance (ANOVA) for categorical and continuous variables, respectively. BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.			

The univariate and multivariate analyses of CD using variables like BMI, VFA, WHR and WC in 50 yrs old males and females are summarized in Table 2. WHR was shown to be strongly related to CD in females using both univariate (OR 0.221, 95% CI 0.057–0.854) and multivariate (OR 0.135, 95% CI 0.032–0.581) analysis. Alternately, in males, both univariate (OR 1.020, 95% CI 1.001–1.039) and multivariate (OR 1.023, 95% CI 1.003–1.024) analysis revealed WC to be closely related to CD.

Table 2
Results of univariate and multivariate analyses of BMI, VFA, WHR, WC and cognitive decline in male and female, respectively (n = 3914).

Unadjusted model								
	BMI		VFA		WHR		WC	
	OR(95% CI)	P-value	OR(95% CI)	P-value	OR(95% CI)	P-value	OR(95% CI)	P-value
M	0.963 (0.912–1.016)	0.169	0.997 (0.991–1.002)	0.233	0.108 (0.01–1.117)	0.062	1.020 (1.001–1.039)	0.034
F	1.015 (0.989–1.043)	0.257	1.000 (0.998–1.003)	0.723	0.221 (0.057–0.854)	0.029	1.002 (0.993–1.012)	0.623
Adjusted model								
	BMI		VFA		WHR		WC	
	OR(95% CI)	P-value	OR(95% CI)	P-value	OR(95% CI)	P-value	OR(95% CI)	P-value
M	0.984 (0.928–1.043)	0.588	0.998 (0.992–1.004)	0.486	0.206 (0.015–2.769)	0.234	1.023 (1.003–1.044)	0.024
F	1.026 (0.998–1.056)	0.073	1.002 (0.999–1.005)	0.212	0.135 (0.032–0.581)	0.007	1.002 (0.992–1.013)	0.675
M, male; F, Female; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area. The multivariate analysis was adjusted for age, ethnic groups, marriage status, education level, occupation and life-style factors (smoking, drinking alcohol and tea), sleeping quality, fertility status, chronic disease comorbidities, depression status. BMI, VFA, WHR and WC were all analyzed as continuous variable.								

In Table 3, we introduced an age stratification. Based on our analysis, BMI was found to be significantly associated with CD in males aged 50–59 yrs (OR 1.116, 95% CI 1.002–1.242). On the other hand, WHR was closely related to CD in females aged ≥ 70 yrs (OR 0.041, 95% CI 0.002–0.671).

Table 3
Multivariate analyses of BMI, VFA, WHR, WC and cognitive decline in male and female in different age groups, respectively(n = 3914).

		BMI		VFA		WHR		WC	
		OR(95% CI)	P-value	OR(95% CI)	P-value	OR(95% CI)	P-value	OR(95% CI)	P-value
50–59	M	1.116(1.002–1.242)	0.047	1.005(0.995–1.016)	0.308	32.26(0.133–7811.27)	0.215	1.035(0.995–1.078)	0.089
	F	1.005(0.957–1.055)	0.855	1.002(0.997–1.007)	0.41	0.172(0.013–2.242)	0.179	1.000(0.983–1.018)	0.970
60–69	M	0.970(0.873–1.078)	0.571	0.995(0.985–1.005)	0.325	0.034(0–3.688)	0.157	1.003(0.969–1.039)	0.855
	F	1.031(0.978–1.087)	0.259	1.003(0.998–1.008)	0.193	0.254(0.017–3.741)	0.318	1.006(0.989–1.022)	0.517
≥ 70	M	0.916(0.825–1.016)	0.097	0.998(0.987–1.008)	0.676	0.006(0–1.387)	0.065	1.03(0.999–1.063)	0.060
	F	1.045(0.993–1.099)	0.091	1(0.994–1.006)	0.990	0.041(0.002–0.671)	0.025	1.005(0.981–1.03)	0.691
M, male; F, Female; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area. The multivariate analysis was adjusted for ethnic groups, marriage status, education level, occupation and life-style factors (smoking, drinking alcohol and tea), sleeping quality, fertility status, chronic disease comorbidities, depression status. BMI, VFA, WHR and WC were all analyzed as continuous variable.									

Table 4 illustrates the multivariate analysis of CD verses VFA, WHR, WC, and BMI. We demonstrated that WHR significantly accelerates CD in participants with BMI < 25 kg/m² (OR 0.022, 95% CI 0.002–0.209).

Table 4
Association of WHR, VFA and WC with cognitive decline under different BMI groups.

	8.5 ≤ BMI<25	BMI ≥ 25
	N = 1775	N = 1987
WHR		
rang	0.29–2.59	0.31–1.55
Mean	0.89 ± 0.08	0.94 ± 0.07
OR,95%CI	0.022(0.002–0.209) **	0.204(0.034–1.211)
Waist		
rang	58.50–146.00	46.60–140.00
Mean	87.30 ± 10.22	87.76 ± 10.35
OR,95%CI	1.006(0.991–26.15)	1.005(0.992–1.018)
VFA		
rang	23.90-224.30	33.00-263.40
Mean	81.66 ± 26.15	133.63 ± 34.75
OR,95%CI	1(0.994–1.006)	1.002(0.998–1.007)
Multivariate analyses of VFA, WHR, WC and cognitive decline under different BMI groups. The multivariate analysis was adjusted for age, gender, ethnic groups, marriage status, education level, occupation and life-style factors (smoking, drinking alcohol and tea), sleeping quality, fertility status, chronic disease comorbidities, depression status. BMI, VFA, WHR and WC were all analyzed as continuous variable. ** p < 0.01.		

Discussion

We performed a large cohort cross-sectional study to investigate the relationship between obesity and CD. Among the 3,914 participants examined in this paper, 13.29% exhibited CD, which increased with age. This is consistent with other studies that reported a close link between aging and CD. In a recent meta-analysis study (n = 80 studies), the prevalence of CD ranged between 5.1% and 41% with a median of 19.0%²⁸. In a separate global study, dementia was shown to affect an estimated 1.8% of people in their 60s, 5.1% of people in their 70s, 15.1% of people in their 80s, and 35.7% of people in their 90s²⁹. Multiple factors are involved in the cognitive dysfunction, including inflammation, insulin resistance, stroke, oxidation and stress, virus infection, and so on³⁰.

In this study, obesity was evaluated by BMI, VFA, WHR, and WC. According to our results, not all obesity indicators were involved in promoting CD. BMI, for instance, accelerated CD in people aged 50–59 yrs. However, with increasing age, particularly, ≥ 60 year, BMI failed to produce a strong effect on CD. This result also corroborates findings from other researchers that demonstrated high BMI in middle age, but not in elderly, contributed to CD^{1,4}. It is yet unclear whether the lack of effect of BMI on CD in later life is accurate or whether a high BMI in elderly is truly protective of cognitive function. To better understand this relationship in later life, further longitudinal studies are warranted.

We also discovered that WHR is positively associated with CD among the elderly population. So, a high WHR was related to a slower CD among ≥ 70 yrs olds. This finding, along with our elderly BMI data, suggests that adiposity

may have a protective effect on cognitive function. In fact, there are a few reports on possible mechanisms of this adipose-cognition relationship¹³. One study, for instance, proposed that estrogen connects excess adipose tissue to improved cognition in the elderly. Elders with more fat cells often have high estrogen levels, due to the peripheral androgen conversion to estrogens, and estrogen is beneficial for cognitive function³¹. In another study, leptin, which is elevated in obese individuals, was suggested to play a role due to its neuroprotective nature³². Indeed, in the Framingham Study, increased leptin levels were shown to be associated with decreased dementia³³. Interestingly, we observed a strong negative association between WHR and CD risk in participants with normal BMI in the fully adjusted model. This indicated that WHR might protect against CD in people with normal BMI. Our WHR findings do not corroborate others findings³⁴ where they showed a positive correlation between WHR and CD risk among elderly with BMI > 25.3 kg/m². Further investigation into this relationship is necessary to understand the complicated nature of WHR regulating CD.

Based on our results, WC was significantly associated with CD in males. But, once we adjusted for age, the relationship was no longer significant. This may be because age attenuated this relationship. Higher WC is normally indicative of central obesity, which is a known risk factor for CD. One study demonstrated that excessive fat mass, measured by WC and adjusted for BMI, was closely related to increased risk of CD³⁵. However, in this study, we did not observe any significant association between WC and CD under any BMI groups. There is more work to be done before a consensus is reached regarding the relationship between WC and CD.

Lastly, our analysis did not show any significant correlation between VFA and CD in the adjusted and unadjusted models. It may be due to our use of the BIA method, instead of CT or MRI which is far more accurate. There are limited studies on the relationship between VFA and CD. One study demonstrated that high VFA quartiles in women were associated with a low risk of non-amnesic MCI⁹. Similarly, another study revealed an inverse relationship between VFA and delayed memory and language scores in T2D³⁶. Further longitudinal studies are warranted for a better understanding of the relationship between VFA and CD.

Limitations

This was a large-population study. As such, caution must be taken in adjusting for essential confounders that might be associated with the study, such as dietary intake. Moreover, this study was primarily observational. A causal relationship between obesity and CD must be explored in future investigations. Lastly, those who volunteered to participate in this study were relatively young and healthy, which may have introduced bias in our results.

Conclusions

Our findings suggest that a high BMI increases the probability of CD in middle aged men. Alternately, increased WHR increased CD risk in elderly women and in individuals with normal BMI. Lastly, our study has not reached a general consensus regarding the relationship between CD and WC or VFA and further investigation is necessary in this regard.

Declarations

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Ethical Statement

Informed consent was provided by each participant or their proxy respondents before

participating in the study. The study was approved by the Ethics Committee of Sichuan University (reference: 2017-445). All the experiment protocol for involving human data was in accordance to guidelines of national/international/institutional or Declaration of Helsinki in the manuscript.

Conflicts of Interest

The authors report no conflicts of interest in this work.

Contributor

Xiaolei Liu and Xiaoyan Chen contributed to conceptualization, data collection, data curation, formal analysis, writing the original draft, and review and editing of the paper. Lisha Hou and Xin Xia contributed to data collection, data curation, and review and editing of the paper. Fengjuan Hu contributed to data collection, data curation. Shuyue Luo contributed to data collection, data curation. Wanyu Zhao contributed to data collection, data curation. Yan Zhang contributed to data collection, data curation. Meiling Ge contributed to data collection, data curation. Gongchang Zhang contributed to data collection, data curation. Birong Dong contributed to study conceptualization, funding acquisition, investigation, methodology, project administration, supervision, and review and editing of the paper.

Availability of Data and Materials

The datasets generated and analyzed during the current study are not publicly available due to this is a newly database which has a lot of important information and we are applying some important projects based on this. But this dataset will be available two years later and is also available now from the corresponding author on a reasonable request.

Consent to publish

Not applicable

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