Association between Body Mass Index and Cognitive Function among Chinese Nonagenarians/Centenarians

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Key Words

Cognitive function · Nonagenarians/centenarians · Body mass index

Abstract

Aims: We examined the individual association between body mass index (BMI) and cognitive function among the very elderly. **Methods:** The present study analyzed data from a survey that was conducted on all residents aged 90 years or more from a district which had 2,311,709 inhabitants in 2005. The subjects were divided into 4 groups according to quartiles of BMI (<16.6, 16.6–18.9, 18.9–21.1 and >21.1), and according to classification criteria of underweight, normal weight, overweight and obesity in BMI (<18.5, 18.5–23.0, 23.0–27.5 and >27.5), respectively. **Results:** The subjects included in the statistical analysis were 211 men and 427 women. Those in the 3rd quartile of BMI (18.9–21.1) had higher cognitive function scores ($p < 0.001$) and were less likely to present possible dementia ($p = 0.016$) than the others. However, there was no difference in cognitive function scores ($p = 0.350$) or prevalence of possible dementia ($p = 0.263$) among obesity, overweight, normal weight and underweight groups. **Conclusions:** Concerning longevity in Chi-

nese, there is an association between BMI and cognitive function. BMI of around 20 (18.9–21.1) is associated with the lowest risk of prevalence of possible dementia and the highest cognitive function scores.

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Introduction

Recent epidemiological studies have associated midlife adiposity with increased risk for dementia in late life, especially Alzheimer's disease [1, 2]. In particular, they made the following associations: (1) atrophy of temporal lobes and greater prevalence of dementia in elderly women with consistently greater body mass index (BMI; an indicator of body adiposity) throughout adulthood [3]; (2) brain atrophy with greater BMI in male and female adults in their 50s [4]; and (3) smaller hippocampal volumes in elderly adults with larger waist/hip ratios (a measure of body fat distribution) [5]. Moreover, several epidemiological studies have identified increased BMI in middle age as a risk factor for diagnosis of dementia a few decades later, especially in women [6–8]. These studies generally accounted for comorbid conditions such as

hypertension, diabetes mellitus, etc. [2], suggesting that body fat has detrimental effects on brain integrity and function. Adiposity appears to have functional relevance because studies found worse learning, memory and executive functioning in obese versus nonobese older adults [9–11]. In addition, Gunstad et al. [12], in a study of young and middle-aged healthy adults, associated being overweight or obese with executive dysfunction. On the other hand, weight loss is common in elderly people with dementia, particularly those with Alzheimer's disease.

It is well known that aging is associated with changes in body composition, including an increase of fat mass and a decline in lean mass. Abdominal fat, largely caused by the accumulation of visceral fat, increases proportionally more with age than peripheral fat [13–16]. Many epidemiological and clinical studies have shown that excess abdominal visceral fat correlates with increased risk for hypertension, dyslipidemia and hyperglycemia [17–19]. Measurement of BMI in older individuals may not adequately reflect abdominal fat accumulation because of the concurrent decrease in muscle mass.

Increased BMI in middle age as a risk factor for diagnosis of dementia a few decades later [1, 2], dementia as a risk factor for weight loss in elderly people [20–22], association between aging and cognitive decline, and association between aging and changes in body composition have all been confirmed [13–16]. From these we can conclude that in the long-lived subjects (aged 90 years or more), there is a close association between BMI and cognitive function, which may be different from that in general older adults (aged 60 years or more). However, to our knowledge, no population-based study has yet evaluated the association of BMI and cognitive function in the long-lived subjects. To help shed light on this area, we examined the association between BMI and dementia in the long-lived subjects using data from a sample of Chinese nonagenarians and centenarians.

Subjects and Methods

Study Subjects

The methods have been reported previously [23, 24]. In brief, on the basis of the Dujiangyan (located in Sichuan province, southwest China) 2005 census, a cross-sectional study for age-related diseases was conducted in 870 long-lived subjects (>90 years), which was a part of the Project of Longevity and Aging in Dujiangyan (PLAD). The PLAD aimed to investigate the relationship between environments, lifestyle, genetics, cognitive function, longevity and age-related diseases. Volunteers were examined by trained professional physicians according to basic health criteria. And the results were filled-in on a standard form, the

questionnaire on lifestyles and cognitive function [measured using the 30-item Mini-Mental State Examination (MMSE)]. We excluded those who did not complete the MMSE test, or had no information on their BMI. Overall, 21 men and 26 women were excluded from the study because they had already died or moved away from the area. Of 262 men and 561 women who were interviewed, 38 men and 125 women did not complete the MMSE test, 6 men and 17 women had no information on their BMI, and 3 men and 8 women both did not complete the MMSE test and had no information on their BMI. Finally, we included 638 participants (221 men, 427 women) in the analysis. Informed consent was obtained from all participants (as well as their legal proxies). The Research Ethics Committee of Sichuan University approved the study.

Data Collection and Measurements

Assessment of Cognitive Function

The methods of assessment of cognitive function have been reported previously [23, 24]. Cognitive function was measured using the 30-item MMSE, which was a global test with components of orientation, attention, calculation, language and recall. To decrease methodological errors and assure methodological reliability, the administrator was given professional training which consisted of: (1) reviewing the MMSE procedure and grading system outlined in a short booklet and video, (2) observing a geriatrician conduct the MMSE on residents not part of the study and (3) receiving supervision while conducting the MMSE on residents not part of the study. The MMSE was administered to individuals who gave consent for study participation. The individuals were categorized as follows: possible dementia (scores between 0 and 18), mild cognitive impairment (scores between 19 and 24) and normal (scores between 25 and 30) [23, 24].

Because the MMSE relied heavily on visual and auditory abilities, especially at advanced ages [25, 26], there was a high prevalence of visual or hearing impairment among nonagenarians and centenarians. Twenty-eight men and 72 women did not complete the MMSE test due to visual or hearing impairment. To address this, these subjects were excluded when the data were analyzed. In the oldest-old sample, only 35 subjects had scores higher than 24 (30 in men, 5 in women); therefore, we merged mild cognitive impairment and normal cognitive function into a nonpossible dementia group when the data were analyzed.

Measurement of BMI

Height and weight were measured according to standardized procedures. BMI was calculated as weight in kilograms divided by height in meters-squared (kg/m^2). Using BMI cutoffs for Asian populations recommended by WHO, we categorized BMI into 4 categories: underweight (<18.5), normal weight (18.5 – 23.0), overweight (23.0 – 27.5) and obesity (≥ 27.5) [27]. Considering the association changes in body composition with aging, cutoff points for underweight, normal weight, overweight and obesity might not be suitable for the long-lived sample, we also categorized BMI into 4 groups using quartile cutoff points: 1st (<16.6), 2nd (16.6 – 18.9), 3rd (18.9 – 21.1) and 4th (≥ 21.1). In the sample, there were 6 men and 17 women who were bedridden, unable to stand, in whom weight and height could not be exactly measured, and for whom BMI could not be accurately calculated. To address this, these subjects were excluded when the data were analyzed [28, 29].

Assessment of Covariates

The baseline examination included information on age (years), gender (male/female), educational levels (illiteracy, primary school, secondary school, college and postgraduate), smoking habits (yes or no), alcohol/smoking habits (yes or no), alcohol consumption (yes or no), tea consumption (yes or no), exercise (yes or no), serum uric acid (mol/l) and BMI [23, 24]. Right arm blood pressure (sitting or recumbent position) was measured twice to the nearest 2 mm Hg using a standard mercury sphygmomanometer (Korotkoff phases I and V) by trained nurses or physicians. Serum lipid/lipoprotein levels [including serum triglyceride (TG), total cholesterol, high-density lipoprotein (HDL) cholesterol and low-density lipoprotein cholesterol], fasting blood glucose and serum uric acid (SUA) were determined by standard laboratory techniques (performed by a technician in the biochemistry laboratory of Sichuan University). The other covariates were collected by using a general question.

Habits of smoking, alcohol consumption, tea consumption and exercise, which included former and current histories, were collected by using a general questionnaire. In the questionnaire, every item had 2 options: yes or no. We defined subjects with such habits as doing it almost everyday. Subjects were asked whether they had ever had habits of smoking, alcohol consumption, tea consumption and exercise, with the following choices of answers (1 only): never, did in the past, or currently. Among those who did, both currently or in the past, information was obtained on the average frequency of smoking, using alcohol, drinking tea and doing exercise and on the number of years they had these habits. The subjects who practiced these habits almost everyday during the recent year were classified as those with these habits currently, otherwise as without. The subjects, who had done these habits almost everyday for more than 2 years as of a year before, were classified as those with these habits previously, otherwise as without. Alcohol consumption included spirits, liqueurs, wine, sherry, martini, beer, lager, cider, stout, etc. Tea consumption included all types of tea. To assure reliability of this information, during the course of interviewing, at least 1 of the family members, who usually lived with the participant, took part in the interviewing and checked the filled-in questionnaire.

Statistical Analysis

All of the statistical analyses for this study were performed with the SPSS for Windows software package, version 11.5 (SPSS Inc., Chicago, Ill., USA). Baseline characteristics were compared among different BMI subgroups using 1-way analysis of variance for continuous variable and Pearson's χ^2 or Fisher's exact test (for which an expected cell count was ≤ 5) for categorical variables. Baseline characteristics were also compared between possible dementia and nonpossible dementia using unpaired Student's *t* test for continuous variables and Pearson's χ^2 or Fisher's exact test (for which an expected cell count was ≤ 5) for categorical variables. Multiple logistic regression was used to estimate the OR and 95% CI of BMI as a function of increased risk for possible dementia. Considering the age, gender and educational levels were viewed as the general factors closely related with cognitive function and BMI, we adjusted them in Model 1. General or central adiposity, elevated blood pressure, dyslipidemia, hyperglycemia and hyperuricemia were viewed as the components of metabolic syndrome and these components might be with the similar mechanism in relation with cognitive function; thus, we adjusted fasting blood

glucose, serum lipid/lipoprotein, blood pressure and SUA in Model 2. Lifestyles (including smoking, alcohol consumption, tea consumption and exercise) might relate with cognitive function and BMI, so we adjusted them in Model 3. Finally, we adjusted all these factors in Model 4. $p < 0.05$ was considered to be statistically significant, and all of the *p* values have 2 sides.

Results

Baseline Characteristics, Cognitive Function and BMI

Among the 638 participants, the mean age was 93.36 years, 64 were centenarians and 427 were women. Ninety percent of participants lived in the countryside. The mean MMSE scores were 15.57 (SD: 5.41). Only 35 volunteers scored higher than 24, so we defined possible dementia as a score lower than 18. In the oldest-old sample, the prevalence of possible dementia was 54.6%, the prevalence rate among males was 39.0% and 67.4% among females ($p < 0.001$). In the sample, the prevalence of possible dementia was associated with educational levels ($p < 0.001$). The subjects with possible dementia were younger in age than those without (93.73 ± 3.40 vs. 93.17 ± 3.28 years, $p = 0.040$). Compared with subjects with possible dementia, those without were more likely to report the habit of tea consumption [current (53.1 vs. 49.2%, $p < 0.001$) and former (56.4 vs. 38.14%, $p < 0.001$)]. Compared with subjects with possible dementia, those without had a lower total cholesterol level (4.06 ± 0.86 vs. 4.20 ± 0.84 mmol/l, $p = 0.036$; table 2).

In the oldest-old sample, the mean of BMI was 19.05 (SD: 3.64). Categorized using widely recognized cutoff points of BMI, 45.5, 43.4, 9.4 and 1.7% of the sample were in underweight, normal weight, overweight and obesity subgroups, respectively. There were different diastolic blood pressure ($p = 0.061$), systolic blood pressure ($p < 0.01$), TG ($p < 0.01$), HDL ($p < 0.01$) and SUA ($p < 0.01$) levels among these different subgroups. Categorized using quartile cutoff points, there were different diastolic blood pressure ($p = 0.040$), systolic blood pressure ($p < 0.01$), TG ($p < 0.01$), HDL ($p < 0.01$) and SUA ($p < 0.01$) levels among these different subgroups. Categorized using both widely recognized cutoff points and quartile cutoff points, there was no significant difference in lifestyles among these different subgroups (table 1).

Cognitive Function in BMI Subgroups

Categorized using widely recognized cutoff points in BMI, the difference in MMSE scores was nonsignificant (15.73 ± 5.29 , 15.52 ± 5.53 , 14.70 ± 5.33 and 15.55 ± 5.99 in underweight, normal weight, overweight and obe-

Table 1. Baseline characteristics according to BMI (n = 638)

Characteristics	All (n = 638)	Diagnostic criteria in BMI				p	Quartile of BMI				p
		underweight (18.5)	normal (18.5–23)	overweight (23–27.5)	obese (27.5)		under 16.6	16.6–18.9	18.9–21.1	above 21.1	
Number, n (%)	638	290 (45.5)	277 (43.4)	60 (9.4)	11 (1.7)		160 (25.1)	160 (25.1)	160 (25.1)	158 (24.7)	
Age, years	93.36 ± 3.17	93.46 ± 3.26	93.30 ± 3.18	93.35 ± 2.90	92.55 ± 2.21	0.781	93.41 ± 3.09	93.56 ± 3.47	93.24 ± 3.20	93.21 ± 2.93	0.761
Male/female	211/427	91/198	100/177	14/46	6/5	0.097	48/112	49/111	61/99	53/105	0.411
MMSE scores	15.57 ± 5.41	15.73 ± 5.29	15.52 ± 5.53	14.70 ± 5.33	15.55 ± 5.99	0.350	15.59 ± 5.20	15.92 ± 5.44	16.37 ± 5.13	14.37 ± 5.71	<0.001**
Dementia											
Yes/no (%)	348/290 (54.6)	162/128 (55.8)	145/132 (52.3)	35/25 (58.3)	6/5 (54.5)	0.263	94/66 (58.8)	82/78 (51.3)	72/86 (45.0)	100/58 (63.3)	0.016*
DBP, mm Hg	72.65 ± 11.20	71.38 ± 11.31	73.33 ± 12.34	74.92 ± 12.90	76.36 ± 13.43	0.061	71.08 ± 12.14	71.60 ± 10.08	73.57 ± 12.79	74.41 ± 12.64	0.040*
SBP, mm Hg	140.08 ± 22.83	136.36 ± 23.17	142.73 ± 22.13	143.43 ± 23.18	153.18 ± 11.46	<0.001**	135.25 ± 24.64	139.28 ± 22.81	142.33 ± 22.79	143.57 ± 20.06	0.001**
TG, mmol/l	1.21 ± 0.64	1.12 ± 0.45	1.22 ± 0.71	1.57 ± 0.83	1.65 ± 1.06	<0.001**	1.12 ± 0.45	1.14 ± 0.48	1.19 ± 0.56	1.44 ± 0.92	<0.001**
TC, mmol/l	4.15 ± 0.85	4.17 ± 0.85	4.06 ± 0.81	4.48 ± 0.95	4.02 ± 0.94	0.006**	4.20 ± 0.90	4.06 ± 0.84	4.07 ± 0.79	4.27 ± 0.86	0.064
HDL, mmol/l	1.58 ± 0.60	1.70 ± 0.77	1.49 ± 0.38	1.42 ± 0.28	1.31 ± 0.24	<0.001**	1.79 ± 0.99	1.55 ± 0.33	1.52 ± 0.42	1.43 ± 0.29	<0.001**
LDL, mmol/l	2.28 ± 0.97	2.27 ± 1.28	2.28 ± 0.58	2.58 ± 0.69	2.29 ± 0.77	0.093	2.33 ± 1.66	2.17 ± 0.60	2.21 ± 0.59	2.42 ± 0.63	0.089
FBG, mmol/l	4.45 ± 1.44	4.48 ± 1.58	4.36 ± 1.26	4.67 ± 1.54	4.70 ± 1.32	0.422	4.59 ± 1.69	4.37 ± 1.37	4.30 ± 1.21	4.54 ± 1.45	0.242
SUA, μ mol/l	318.78 ± 87.50	303.31 ± 90.94	327.19 ± 80.86	350.82 ± 89.47	334.18 ± 77.73	<0.001**	299.96 ± 94.43	304.55 ± 79.99	333.38 ± 84.73	337.65 ± 84.64	<0.001**
Smoking habits											
Former, yes/no	389/234	163/119	179/94	40/18	7/3	0.398	91/64	91/69	102/56	105/45	0.130
Current, yes /no	284/352	127/162	125/151	26/34	6/5	0.901	73/86	67/96	73/87	71/83	0.771
Alcohol consumption											
Former, yes/no	254/373	117/169	110/163	20/38	7/3	0.212	68/89	65/97	66/90	55/97	0.591
Current, yes/no	170/465	79/209	70/206	13/47	8/3	0.005**	49/109	40/123	41/119	40/114	0.568
Tea habits											
Former, yes/no	342/280	132/154	120/147	24/35	4/6	0.873	76/83	70/90	65/88	69/80	0.788
Current, yes/no	269/368	124/165	116/161	22/38	7/4	0.408	72/87	65/98	60/100	72/83	0.311
Exercise habits											
Former, yes/no	208/412	98/184	88/182	19/40	3/6	0.952	46/109	62/97	53/102	47/104	0.310
Current, yes/no	263/368	125/162	107/166	26/34	5/6	0.743	59/99	77/84	63/94	64/91	0.274
Educational levels											
Illiteracy	345	157	149	33	6		87	81	90	87	
Primary school	137	62	57	15	3		31	35	37	34	
Secondary school	58	22	27	7	2		14	13	15	16	
College and Postgraduate	26	10	11	4	1	0.823	4	7	7	8	0.523

Baseline characteristics were compared between different BMI groups, using 1-way analysis of variance for continuous variables and Pearson's χ^2 or Fisher's exact test (for which an expected cell count was <5) for categorical variables. In the testing, $p < 0.05$ was considered to be statistically significant. FBG = Fasting blood glucose; LDL = low-density lipoprotein; TC = total cholesterol; SBP = systolic blood pressure; DBP = diastolic blood pressure. * $p < 0.05$; ** $p < 0.01$.

Table 2. Baseline characteristics according to cognitive function (n = 638)

Characteristics	All (n = 638)	Nonpossible dementia (n = 290)	Possible dementia (n = 348)	p
Age, years	93.52 ± 3.37	93.73 ± 3.40	93.17 ± 3.28*	0.040*
Male/female	211/427	75/276	136/151	<0.001**
DBP, mm Hg	72.65 ± 11.20	72.08 ± 12.08	72.91 ± 12.05	0.388
SBP, mm Hg	140.08 ± 22.83	139.71 ± 23.31	140.07 ± 22.63	0.862
TG, mmol/l	1.21 ± 0.64	1.19 ± 0.54	1.24 ± 0.70	0.283
TC, mmol/l	4.15 ± 0.85	4.06 ± 0.86	4.20 ± 0.84*	0.036*
HDL, mmol/l	1.58 ± 0.60	1.59 ± 0.66	1.57 ± 0.54	0.222
LDL, mmol/l	2.28 ± 0.97	2.27 ± 0.59	2.28 ± 1.17	0.810
FBG, mmol/l	4.45 ± 1.44	4.45 ± 1.52	4.47 ± 1.40	0.883
SUA, µmol/l	318.78 ± 87.50	321.17 ± 92.73	316.88 ± 82.53	0.534
BMI	19.05 ± 3.64	18.93 ± 3.25	19.11 ± 3.85	0.530
Smoking habits				
Former, yes/no	389/234	150/87	239/147	0.752
Current, yes/no ^a	284/352	110/137	174/225	0.667
Alcohol consumption				
Former, yes/no ^a	254/373	106/132	148/241	0.097
Current, yes/no ^a	170/465	70/173	100/292	0.416
Tea habits				
Former, yes/no ^a	280/342	132/102	148/240	<0.001**
Current, yes/no ^a	269/368	129/114	140/254	<0.001**
Exercise habits				
Former, yes/no ^a	208/412	83/153	125/259	0.271
Current, yes/no ^a	263/368	109/132	154/236	0.093
Educational levels				
Illiteracy	345	146	199	
Primary school	137	68	69	
Secondary school	58	30	28	
College and postgraduate	26	17	9	<0.001**

Baseline characteristics were compared between different BMI groups. * $p < 0.05$ and ** $p < 0.01$ vs. nonpossible dementia, using χ^2 or Fisher's exact test (where an expected cell count was <5) for categorical variables and unpaired Student's t test for continuous variables. FBG = Fasting blood glucose; LDL = low-density lipoprotein; TC = total cholesterol; SBP = systolic blood pressure; DBP = diastolic blood pressure.

^a $p < 0.05$ was considered to be statistically significant.

sity subgroups, respectively, $p = 0.350$) and the difference in prevalence of possible dementia was also nonsignificant (55.8, 52.3, 58.3 and 54.5% in underweight, normal weight, overweight and obesity subgroups respectively, $p = 0.263$; table 1).

Categorized using quartile cutoff points in BMI, there were significantly different MMSE scores (15.59 ± 5.20 , 15.92 ± 5.44 , 16.37 ± 5.13 and 14.37 ± 5.71 in subgroups from the lowest to highest, respectively, $p < 0.001$) and prevalence of possible dementia (58.8, 51.3, 45.0 and 63.3% in subgroups from the lowest to highest, respectively, $p = 0.016$). The 3rd quartile of BMI (18.9–21.1) showed the highest MMSE scores and the lowest preva-

lence of possible dementia among the 4 subgroups (table 1). This showed an association between BMI and MMSE scores or the prevalence of possible dementia.

BMI and the Risk for Dementia

Categorized using widely recognized cutoff points of BMI, unadjusted and adjusted ORs for possible dementia among underweight, normal weight, overweight and obesity subgroups were nonsignificant.

Categorized using quartile cutoff points of BMI, the 3rd quartile (18.9–21.1) had significantly decreased ORs for possible dementia (OR: 0.589, 95% CI: 0.383–0.935; OR: 0.614, 95% CI: 0.371–0.918; OR: 0.602, 95% CI: 0.376–

Table 3. Effect of BMI on cognitive function in long-lived subjects

Characteristics	Diagnostic criteria in BMI				Quartile of BMI			
	underweight OR (95% CI)	normal weight OR (95% CI)	overweight OR (95% CI)	obese OR (95% CI)	under 16.6 OR (95% CI)	16.6–18.9 OR (95% CI)	18.9–21.1 OR (95% CI)	above 21.1 OR (95% CI)
Unadjusted	1.000 (ref.)	0.955 (0.913–1.315)	1.087 (0.762–1.534)	0.981 (0.851–1.384)	1.000 (ref.)	0.739 (0.458–1.161)	0.589 (0.383–0.935)*	1.178 (0.746–1.859)
Model 1	1.000 (ref.)	1.027 (0.944–1.437)	1.110 (0.814–1.437)	1.009 (0.857–1.519)	1.000 (ref.)	0.731 (0.463–1.157)	0.614 (0.371–0.918)*	1.248 (0.785–2.001)
Model 2	1.000 (ref.)	0.974 (0.901–1.276)	0.935 (0.813–1.368)	0.888 (0.636–1.568)	1.000 (ref.)	0.725 (0.444–1.135)	0.602 (0.376–0.963)*	1.176 (0.724–1.927)
Model 3	1.000 (ref.)	0.961 (0.975–1.284)	1.036 (0.872–1.451)	0.975 (0.801–1.279)	1.000 (ref.)	0.759 (0.498–1.270)	0.660 (0.411–0.991)*	1.470 (0.903–2.391)
Model 4	1.000 (ref.)	1.107 (0.963–1.385)	1.145 (0.877–1.494)	1.150 (0.835–1.468)	1.000 (ref.)	0.733 (0.445–1.119)	0.719 (0.418–0.999)*	1.539 (0.895–2.673)

Adjusted multiple logistic regression was used to adjust for covariates; unadjusted: Wald χ^2 with d.f. = 1 was used. Model 1: adjustment made with age, gender and educational levels; Model 2: adjustment made with the other components of metabolic syndrome (blood pressure, serum lipid/lipoprotein, blood sugar, uric acid), age, gender and educational levels; Model 3: adjustment made with lifestyles (smoking habits, alcohol consumption, tea habits, exercise habits), age, gender and educational levels; Model 4: adjusted for all factors above.

* $p < 0.05$.

0.963; OR: 0.660, 95% CI: 0.411–0.991; OR: 0.719, 95% CI: 0.418–0.999 in the unadjusted model as well as adjusted Models 1, 2, 3 and 4, respectively).

Discussion

This study evaluated the association between BMI and cognitive function in long-lived subjects. In the cross-sectional observations, categorized using quartile cutoff points of BMI, the 3rd subgroup (18.9–21.1) had lower risk for possible dementia and higher MMSE scores than the others; however, categorized using classification criteria (underweight, normal weight, overweight and obesity), normal weight (18.5–23.0) were no different in risk for possible dementia or MMSE scores than the others.

In the present study, according to classification criteria (underweight, normal weight, overweight and obesity) of BMI in the general population, there was a high prevalence of underweight (45.5%), and there were more underweight subjects than those with normal weight. The sample was from a community population, with the prevalence of underweight in younger adults less than 5% in the Chinese community population. Among elderly Chinese community dwellers (aged 60 years or above), the prevalence of underweight was lower than 10% [30, 31]. Aging was related with changes in body composition (in-

cluding a decrease of BMI), and this finding was consistent with that of previous reports [13–16].

In the present study, subjects with BMI of 18.9–21.1 had lower risk for possible dementia than the others. However, MMSE scores or the prevalence of possible dementia in subjects with BMI of 18.5–23.0 was not different from the others. Those with BMI of 18.5–23.0 included 87 (31.5%) with 21.1–23.0, 160 (57.7%) with 18.9–21.1 and 30 (10.8%) with 18.5–18.9. Those with BMI of 18.5–23.0, but not from 18.9–21.1, removed the favorable effect on cognitive function of the BMI of 18.9–21.1. This indicated that among Chinese long-lived subjects, BMI around 20 (18.9–21.1) was the most favorable for prevention of dementia.

Focusing on the relationship between BMI and cognitive functioning, previous studies showed that the relationship between high BMI or obesity and cognitive status were inconsistent [1, 32–36], but most studies suggested that low BMI was related to dementia risk [33–36]. Our study provided evidence from Chinese community dwellers, and showed low and high BMI were both related to poorer cognitive function, even in cases where they did not meet the diagnostic criteria of underweight and overweight in BMI for Asian populations recommended by WHO.

In contrast to almost all previous studies, the standard used in this study was the MMSE rather than clinical di-

agnosis of dementia, as an extensive clinical evaluation of 870 nonagenarians/centenarians in their home in this community of 2,311,709 inhabitants was impractical. The MMSE was only a screening test for dementia, which is also widely used to detect cognitive function. The MMSE score did not always reflect the exact cognitive function because it had been shown that it was sometimes influenced by age, gender and the level of education of the subject. In the present study, the subjects with better education had lower possible dementia. This finding was consistent with that of previous reports [37, 38]. However, in the present study, after adjusting for age, gender and the level of education, BMI around 20 (18.9–21.1) still had a significantly decreased OR for possible dementia. These results strongly suggest that BMI of around 20 (18.9–21.1) was an important determinant factor of cognitive function in aged individuals. The finding has practical implications for interventions to prevent dementia. In our community-dwelling Chinese nonagenarians and centenarians, in order to maintain better cognitive function, 50% of them should have a higher BMI, and 25% should have a lower BMI, as the most appropriate BMI is around 20 (18.9–21.1).

The association between high BMI and cognitive function can be accounted for by the following: high BMI in long-lived subjects was related to increased BMI in middle age, which was viewed as a risk factor for a diagnosis of dementia a few decades later [1, 2]; and together with obesity, hypertension, dyslipidemia, hyperuricemia and diabetes were viewed as metabolic syndrome components. Metabolic syndrome has been confirmed as the risk factor for dementia [6–8, 39]. In the present study, the subjects with high BMI had high blood pressure, TG, SUA levels and low HDL levels, and those with possible dementia had higher total cholesterol levels than those without. Lifestyles such as smoking, alcohol, tea and exercise habits were related with both cognitive function and BMI [40, 41]. In the present study, subjects with possible dementia had higher prevalence of tea habits than those without.

The association between low BMI and cognitive function can also be accounted for with weight loss in subjects with dementia [20–22], and changes in body composition (resulting in decreased BMI) and dementia were both related with aging [13–16]. Subjects who were both obese and who had dementia had a high mortality rate [42]. The high mortality rate in long-lived subjects might very likely remove those with high BMI and dementia, and leave moderate or severe dementia subjects with low BMI, enforcing the association between BMI and dementia.

Our study had some limitations that deserve mention. First, 870 subjects aged 90 years or older volunteered for the PLAD Study. Among these 870 volunteers, only 638 had nonmissing data for the 2 main variables involved in the current analyses. There might be selection biases. Because the MMSE relied heavily on visual and auditory abilities, especially at advanced ages, for subjects who were bedridden or unable to stand, it was difficult to be measure weight and height, and BMI could not be calculated. Among nonagenarians and centenarians, there was a high prevalence of visual or hearing impairment and being bedridden. We excluded those with visual or hearing impairment or being bedridden. However, the information from them might be unable to influence the practical implications of the present study. Second, because of the cross-sectional nature of this study, the subjects might change their diets and the conditions related to BMI. However, the lifestyles and food habits of the nonagenarians/centenarians were relatively stable and similar. Third, because of the cross-sectional nature of this study, we only concluded the association between BMI and dementia. We could not conduct causal conclusions on it. Fourth, since this is a part of the PLAD, there might be a survival bias. However, this is inherent in a study of individuals of this age group.

In conclusion, concerning longevity in Chinese, there is an association between BMI and cognitive function. BMI around 20 (18.9–21.1) is associated with the lowest risk of prevalence of possible dementia and the highest cognitive function scores.

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