Association between sleep quality and body mass index among Chinese nonagenarians/centenarians

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Received: 3 November 2010 / Accepted: 10 April 2011 / Published online: 18 May 2011
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Abstract We examined the individual association between body mass index (BMI) and sleep quality among the very elderly. The present study analyzed data from survey that was conducted on all residents aged 90 years or more in a district, there were 2,311,709 inhabitants in 2005. Subjects were divided into four groups according to quartile of BMI (<16.6 , 16.6 – 18.9 , 18.9 – 21.1 , >21.1 kg/m²) and according to classification criteria of underweight, normal weight, overweight, and obesity in BMI (<18.5 , 18.5 – 23.0 , 23.0 – 27.5 , >27.5 kg/m²), respectively. Sleep quality was measured using The Pittsburgh Sleep Quality Index (PSQI). Sleep quality included quality classification and scores, sleep duration, sleep latency, and sleep efficiency. The subjects included in the statistical analysis were 216 men and 444 women. According to quartile of BMI or classification

criteria of underweight, normal weight, overweight, and obesity in BMI, none of the differences in sleep quality scores, sleep latency, sleep duration, sleep efficiency percentage, and prevalence of poor sleep quality was significant among different BMI groups. The difference in BMI between subjects with good and poor sleep quality was non-significant. Unadjusted and adjusted multiple logistic regression showed that none of the BMI groups had a function of decreasing the risk for poor quality. Among longevity Chinese, there is no association between BMI and sleep quality.

Keywords Sleep quality · Body mass index · Nonagenarians/Centenarians

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Introduction

Sleep is an important modulator of neuroendocrine function and glucose metabolism in children as well as in adults (Van Cauter and Knutson 2008; Keith et al. 2006; Spiegel et al. 1999). In recent years, sleep curtailment has become a hallmark of modern society with both children and adults having shorter bedtimes than a few decades ago. This trend for shorter sleep duration has developed over the same time period as the dramatic increase in the prevalence of obesity (Van Cauter and Knutson 2008; Prevalence and trends in obesity among US adults 2002). There is rapidly accumulating evidence from both laboratory and epidemiological studies to indicate that chronic partial

sleep loss may increase the risk of obesity and weight gain (Patel and Hu 2008; Zee and Turek 2006; Lopez-Garcia et al. 2008; Rao et al. 2009). The previous studies provided laboratory and clinical evidence indicating that sleep curtailment in young adults results in a constellation of metabolic and endocrine alterations, including decreased glucose tolerance, decreased insulin sensitivity, elevated sympathovagal balance, increased evening concentrations of cortisol, increased levels of ghrelin, decreased levels of leptin, and increased hunger and appetite (Patel and Hu 2008; Zee and Turek 2006; Lopez-Garcia et al. 2008; Rao et al. 2009; Spiegel et al. 2004; Littman et al. 2006; Gangwisch et al. 2005; Erik Landhuis et al. 2008).

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 (Horber et al. 1997; Snijder et al. 2006; Wang et al. 1994; Zamboni et al. 1997). Measurement of body mass index (BMI) in older individuals may not adequately reflect abdominal fat accumulation because of the concurrent decrease in muscle mass, and on the other hand, sleep is also a vital physiologic process with important restorative functions (Nevitt et al. 1989; Ohayon et al. 2004; Redline et al. 2004). Notable qualitative and quantitative changes in sleep occur with age (Nevitt et al. 1989; Ohayon et al. 2004; Redline et al. 2004). Aging is associated with several well-described changes in patterns of sleep with age (Jean-Louis et al. 2000). It is well known that both sleep quality and BMI are strongly influenced by lifestyles (Lamberg 2006; Bauer et al. 2010; French et al. 2010; Shinba et al. 1994). Less exercise and smoking are linked with the risk for obesity or chronic insomnia (Lamberg 2006; Bauer et al. 2010). It has been confirmed that there is a U-shaped association between alcohol consumption and obesity or chronic insomnia (French et al. 2010; Shinba et al. 1994). Both sleep disorders and obesity are associated with the high mortality risk (Grandner et al. 2010; Karra and Batterham 2010).

Shorter sleep duration as a risk for increased BMI (Van Cauter and Knutson 2008; Patel and Hu 2008), obesity individuals more likely with sleep disorders (Vgontzas 2008), some lifestyles (exercise, smoking, alcohol consumption, and so on) relating with the risk

factors for both sleep disorders and obesity (Lamberg 2006; Bauer et al. 2010; French et al. 2010; Shinba et al. 1994), both sleep disorders and obesity as risk factors for high mortality in the elderly (Grandner et al. 2010; Karra and Batterham 2010), and BMI and sleep disorders both relating with age have all been confirmed (Horber et al. 1997; Snijder et al. 2006; Wang et al. 1994; Zamboni et al. 1997; Nevitt et al. 1989; Ohayon et al. 2004; Redline et al. 2004). From all of these, we can conclude that in the long-lived subjects (aged 90 years or more), there is a close association between sleep quality and BMI, which may be different from that in general population. However, to our knowledge, no population-based study has yet evaluated the association between sleep quality and BMI in the long-lived subjects. To do it, using data from a sample of Chinese nonagenarians and centenarians, we examined the association between sleep quality and BMI in the long-lived subjects.

Subjects and methods

Study subjects

The methods were reported previously (Huang et al. 2009a, b). 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 Doujiangyan (PLAD). The PLAD aimed to investigate the relationship between environments, lifestyle, genetic, cognitive function, sleep quality, longevity, and age-related diseases among long-lived subjects in the community. Volunteers were examined by trained professional physicians according to basic health criteria in their home, and the results were filled in the standard form, especially questionnaire on lifestyles and sleep quality (measured using The Pittsburgh Sleep Quality Index (PSQI)). In this analysis, the subjects were bedridden, or with cancer, a history or clinical evidence of stroke, terminal stage of physical disease such as respiratory system disease, cardiovascular disease, kidney diseases and so on, were excluded. Overall, 21 men and 26 women were not eligible for the study because they had already died or moved away from the area. Of 262 men and 561

women who were interviewed, 46 men and 117 women were excluded for the reason above. The study population ultimately consisted of 660 long-lived subjects. Informed consents were obtained from all participants (as well as their legal proxies). The Research Ethics Committee of the Sichuan University approved the study. To assure reliability of this information, during the course of interviewing, at least one of the family members, who usually lived with the participant, took part in the interviewing and checked the filled questionnaire.

Data collection and measurements

Measurement of sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used for the subjective assessment of sleep quality (Buysse et al. 1989). To decrease methodological errors and assure methodological reliability, the administrator reviewed the PSQI procedure and grading system outlined in a short booklet and video, observed a psychogeriatrician conducting the PSQI on residents not part of the study and was supervised when conducting the PSQI on residents not part of the study. The PSQI is a questionnaire consisting of 19 items which are coded on a 4-point scale (0–3) to obtain seven subcategories, including sleep duration, sleep disturbances, sleep latency, daytime dysfunction, sleep efficiency, sleep satisfaction, and medication use. The sum of all subscores represents the total sleep quality score, ranging between 0–21, with higher scores representing lower sleep quality. The individuals were categorized as follows: good sleep quality (scores between 0 and 5) and poor sleep quality (scores between 6 and 21). Respondents are asked to rate their sleep reflecting on the past month. Psychometric properties have demonstrated good reliability (internal consistency 0.89; test retest reliability 0.85) and good construct validity for the English language version (Shochat et al. 2007). The PSQI is a widely used tool in research studies and clinical trials and has been translated to several languages including Chinese, Spanish, German, and Hebrew, with comparable reliability and validity values. Internal consistency in the present study was $\alpha=0.69$. When excluding the medication use subscale due to a low rate of medication users in this sample, internal consistency increased to $\alpha=0.76$ (Zisberg et al. 2010). Outcome measures included the total PSQI score

as well as self report of sleep latency (SL) (question 2: how long (in minutes) has it usually taken you to fall asleep each night?), sleep duration (total time in bed: hours computed based on reported bedtime in question 1: what time have you usually gone to bed at night? and reported wake-time in question 3: what time have you usually gotten up in the morning?) and sleep efficiency percentage (SE) computed as the ratio between the hours of actual sleep (question 4: how many hours of actual sleep did you get at night?) and total time in bed, multiplied by 100 (Shochat et al. 2007; Zisberg et al. 2010). Forty-six men and 117 women were bedridden, or with cancer, a history or clinical evidence of stroke, terminal stage of physical disease such as respiratory system disease, cardiovascular disease, kidney disease, and so on. These subjects usually had longer bed time and poor sleep quality, and sleep quality in them could not be accurately calculated. To address this, these subjects were excluded when the data were analyzed.

Measurement of the 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 four categories: underweight ($<18.5 \text{ kg}/\text{m}^2$), normal weight ($18.5\text{--}23.0 \text{ kg}/\text{m}^2$), overweight ($23.0\text{--}27.5 \text{ kg}/\text{m}^2$), and obesity ($\geq 27.5 \text{ kg}/\text{m}^2$) (WHO Expert Consultation 2004). 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 four groups using quartile cutoff points: the first ($<16.6 \text{ kg}/\text{m}^2$), the second ($16.6\text{--}18.9 \text{ kg}/\text{m}^2$), the third ($18.9\text{--}21.1 \text{ kg}/\text{m}^2$), and the fourth ($\geq 21.1 \text{ kg}/\text{m}^2$). In the sample, there were 6 men and 17 women bedridden, unable to stand, who could not be exactly measured in weight and height, and BMI could not be accurately calculated. To address this, these subjects were excluded when the data were analyzed (Drøyvold et al. 2006; Scholtens et al. 2007).

Assessment of covariates

The baseline examination included information on age (Years), gender (Male/Female), smoking habits (Yes or No), alcohol consumption (Yes or No), tea

consumption (Yes or No), exercise (Yes or No), nap in daytime (Eve/Usu/Occ/Never), cognitive function, waist circumference, serum lipid/lipoprotein levels (including serum triglyceride (TG), total cholesterol (TC), high-density-lipoprotein (HDL) cholesterol, and low-density-lipoprotein (LDL) cholesterol), fasting blood glucose (FBG), serum uric acid (SUA) (mole per liter) and blood pressure (Huang et al. 2009a, b). Right arm blood pressure (sitting or recumbent position) was measured twice to the nearest 2 mmHg using a standard mercury sphygmomanometer (Korotkoff phases I and V) by trained nurses or physicians. Waist circumference was measured about 1 cm below the belly button, stand up straight, breathe out, do not hold your breath or tuck in your stomach; make sure the measuring tape is not too loose or too tight around your waist; when take reading, make sure it was not held the tape at an angle. Serum lipid/lipoprotein levels, FBG, and SUA were determined by standard laboratory techniques (performed by a technician in the biochemistry laboratory of Sichuan University). Cognitive function was measured using the 30-item Mini-Mental State Examination (MMSE), which was a global test with components of orientation, attention, calculation, language, and recall. The other covariates were collected by using a general question.

Habits of smoking, alcohol consumption, tea consumption, and exercise, which included former and current, were collected by using a general questionnaire. In the questionnaire, every item had two options (yes or no). We defined subjects with such habit as doing it almost everyday. Subjects were asked whether they had ever had habits of smoking, alcohol consumption, tea consumption, and exercise, and one of three answers were recorded: never, did in the past, or currently. Among those who did, 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 did for. The subjects, who did almost everyday during the recent 1 year, were classified as those with these habits current, otherwise as without. The subjects, who had done 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, and so on. Tea consumption included all types of tea.

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, Illinois, USA). Baseline characteristics were compared among different BMI subgroups using one-way analysis of variance for continuous variable and Pearson Chi-Square or Fisher's exact test (whereas an expected cell count was <5) for categorical variables. Baseline characteristics were also compared between good and poor sleep quality using unpaired Student's *t* test for continuous variables and Pearson Chi-Square or Fisher's exact test (whereas an expected cell count was <5) for categorical variables. Multiple logistic regression was used to estimate the odds ratio (OR) and 95% confidence interval (CI) of BMI as a function of increased risk for poor sleep quality. Considering 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 sleep quality; thus, we adjusted FBG, waist circumference, serum lipid/lipoprotein, blood pressure, and SUA in mode 1. Lifestyles (including smoking, alcohol consumption, tea consumption, and exercise) might relate with sleep quality and BMI, so we adjusted them in mode 2. Finally, we adjusted age, gender, nap in daytime, cognitive function, and all factors above in model 3. *P* value <0.05 was considered to be statistically significant, and all of the *P* values have two sides.

Results

Baseline characteristics, sleep quality, and BMI

Among the 660 participants, mean age was 93.52 years, 69 were centenarians and 444 were women. Ninety percent of participants lived in the country side. There were 513 (77.8%) and 147 (22.2%) with good and poor sleep quality, respectively. The mean sleep quality score was 6.84 ± 2.15 , the mean SL was 45.89 ± 16.72 min, the mean SE was $76.53 \pm 8.78\%$, the mean sleep duration was 10.21 ± 1.55 h, and of them, 0.91%, 1.97%, 27.73%, and 69.39% were in <6/6–7/8–9/>10(h) sleep duration subgroups, respectively (see Table 1).

Table 1 Baseline characteristics according to sleep quality ($n=660$)

Characteristics	All ($n=660$)	Good sleep quality ($n=513$)	Poor sleep quality		
			($n=147$)	χ^2 or t	P value
Age (years)	93.52 $\pm$ 3.37	93.48 $\pm$ 3.40	93.63 $\pm$ 3.14	0.499	0.618
Gender					
Male/Female	216/444	174/339	42/105	0.219	0.803
Nap in daytime					
Eve/Usu/Occ/Never	186/101/80/264	134/80/63/214	52/21/17/50	4.035	0.258
MMSE scores	15.48 $\pm$ 5.44	15.85 $\pm$ 5.41	14.24 $\pm$ 5.27	3.156	0.002**
BMI kg/m ²	19.05 $\pm$ 3.64	18.99 $\pm$ 3.76	19.20 $\pm$ 3.85	0.593	0.554
<18.5/18.5–23/23–27.5/>27.5	300/286/62/12	238/217/50/8	61/71/12/3	1.922	0.589
<16.6/16.6–18.9/18.9–21.1/>21.1	166/166/166/162	126/126/120/120	33/32/39/33	1.023	0.796
Waist circumference cm	76.60 $\pm$ 9.51	76.81 $\pm$ 9.23	76.05 $\pm$ 10.43	0.851	0.359
DBP(mmHg)	72.59 $\pm$ 12.06	72.70 $\pm$ 11.96	72.23 $\pm$ 12.65	0.408	0.683
SBP(mmHg)	139.71 $\pm$ 23.31	139.75 $\pm$ 22.96	140.37 $\pm$ 22.78	0.286	0.775
TG (mmol/L)	1.22 $\pm$ 0.64	1.22 $\pm$ 0.66	1.25 $\pm$ 0.58	0.445	0.657
TC (mmol/L)	4.15 $\pm$ 0.85	4.16 $\pm$ 0.84	3.97 $\pm$ 0.88	0.567	0.561
HDL (mmol/L)	1.58 $\pm$ 0.59	1.56 $\pm$ 0.38	1.63 $\pm$ 1.02	1.335	0.182
LDL (mmol/L)	2.28 $\pm$ 0.97	2.25 $\pm$ 0.60	2.40 $\pm$ 0.97	1.666	0.096
FBG(mmol/L)	4.46 $\pm$ 1.45	4.43 $\pm$ 1.36	4.57 $\pm$ 1.68	1.000	0.318
SUA (μ mol/L)	318.72 $\pm$ 87.01	317.95 $\pm$ 85.70	321.45 $\pm$ 93.10	0.424	0.672
Smoking habits					
Former (Yes/No) a	242/395	192/302	50/93	1.007	0.605
Current (Yes/No)	361/289	277/229	84/60	0.585	0.647
Alcoholic					
Former (Yes/No) a	379/262	295/202	84/60	0.048	0.848
Current(Yes/No) a	176/473	143/361	33/112	1.796	0.180
Tea habits					
Former (Yes/No) a	287/349	224/271	63/78	0.014	0.904
Current (Yes/No) a	275/376	217/289	58/87	0.385	0.535
Exercise habits					
Former (Yes/No) a	214/420	167/327	47/93	0.003	0.999
Current (Yes/No) a	265/380	206/296	59/84	0.002	1.000

Baseline characteristics were compared between different sleep quality groups

SUA serum uric acid, *BMI* body mass index, *FBG* fasting blood glucose, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *TC* total cholesterol, *TG* triglyceride, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *MMSE* Mini-Mental State Examination

* $P<0.05$, ** $P<0.01$ vs. good sleep quality (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)

^a Fisher's exact test

In the oldest-old sample, the mean of BMI was 19.05 (s.d. 3.64). Categorized using widely recognized cutoff points of BMI, 45.5%, 43.4%, 9.4%, and 1.7% were in underweight, normal weight, overweight, and obesity subgroups, respectively. There were different DBP ($P=0.061$), SBP ($P<0.01$), 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 DBP ($P=0.040$), SBP ($P<0.01$), 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 in BMI (see Table 2).

No association between BMI and quality of sleep

Between the different sleep quality groups, the difference in BMI was non-significant (18.99 ± 3.76 vs. 19.20 ± 3.85 , between subjects with good and poor sleep quality, respectively, $P=0.554$) (see Table 1). Categorized using widely recognized cutoff points in BMI or quartile cutoff points in BMI, among the different subgroups, none of the differences in sleep quality scores, sleep latency, sleep efficiency percentage, sleep duration, and prevalence of poor sleep quality was significant. Unadjusted and adjusted multiple logistic regression showed that none of the BMI groups had a function of decreasing the risk for poor quality. All of these showed that among long-lived subjects, there was no association between sleep quality and BMI (Table 3).

Discussion

This study evaluated the association between sleep quality and BMI in the long-lived subjects. In the present study, sleep quality included quality classification and scores, sleep duration, sleep latency, and sleep efficiency. According to cutoffs for Asian populations recommended by WHO and quartile cutoff points in BMI, the subjects were divided into four groups, respectively. In the cross-sectional observations, in the long-lived community dwellers, there was no association between sleep quality and BMI.

In the present study, we found that there was no association between sleep quality and BMI in the long-lived community dwellers, which was different from that in general population (Van Cauter and Knutson 2008; Spiegel et al. 1999; Prevalence and trends in obesity among US adults 2002; Patel and Hu 2008; Gangwisch et al. 2005; Erik Landhuis et al. 2008). This finding was interesting, and the difference between long-lived community dwellers and general population in association between sleep quality and BMI could be accounted for the changes in body composition with age and the changes in sleep patterns with age (Horber et al. 1997; Snijder et al.

2006; Wang et al. 1994; Zamboni et al. 1997; Nevitt et al. 1989; Ohayon et al. 2004; Redline et al. 2004).

In the present study, according to classification criteria (of underweight, normal weight, overweight, and obesity) in BMI in 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, the prevalence of underweight in younger adults was less than 5% in Chinese community dwellers. Among elderly community dwellers (aged 60 years or above) in Chinese, the prevalence of underweight was lower than 10% (Lau et al. 2005; Chan et al. 1998). In the present study, BMI in many subjects is low, that about one fourth of them is lower than 16.6 kg/m^2 . Although symptoms of malnutrition do not be need to included in the survey, subjects being bedridden or with severe disease were excluded from our study. In fact, our sample was rural health longevity. So there was no subject with malnutrition caused by diseases. In the survey, the socio-economic parameters were included, and the incomes of the subjects were all 2,000–4,000 yuan (about 350–700 dollars)/month/person in family. So there was also no subject with malnutrition caused by the poor socio-economic parameters. Therefore, it is impossible for malnutrition to lead the low BMI in the sample. Obesity led to mortality through inducing cardiovascular disease and the other components of metabolic syndrome; however, the prospective studies showed that the elderly with body weight loss had higher mortality than those without, so the low BMI was not from high mortality in the long-lived subjects and more likely from changes in body composition (including a decrease of BMI) with aging. This finding was consistent with that of previous reports (Wang et al. 1994). In the present study, according to classification criteria widely recognized cutoff points in BMI or quartile cutoff points in BMI, there was non-significantly different sleep quality among BMI subgroups. This indicated that in the association of BMI with sleep quality, the difference between the long-lived subjects and general population was not from the classification criteria in BMI.

In the present study, the mean sleep duration was 10.21 ± 1.55 h, and of them, 0.91%, 1.97%, 27.73%, and 69.39% were in <6/6–7/8–9/>10(h) sleep duration subgroups, respectively. In Chinese, the mean sleep duration was less than 9 h in general population.

Table 2 Baseline characteristics according to BMI (kg/m²) (*n*=660)

Characteristics	All (<i>n</i> =660)	Diagnostic criteria in BMI			Quartile of (BMI)				<i>P</i> value
		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	
Number (<i>n</i> , %)	660	300, 45.5%	286, 43.4%	62, 9.4%	12, 1.7%	166, 25.1%	166, 25.1%	166, 25.1%	
Age (years)	93.52±3.37	93.46±3.26	93.30±3.18	93.35±2.90	92.55±2.21	93.41±3.09	93.56±3.47	93.24±3.20	0.761
Gender									
Male/Female	216/444	93/207	103/183	14/48	6/6	49/117	51/115	62/104	0.411
Sleep quality									
Score	6.84±2.15	6.61±3.01	6.73±1.58	8.42±3.15	7.07±2.26	6.69±2.98	6.71±2.29	7.13±3.06	0.566
Poor sleep quality (%)	21.78	20.00	24.09	18.64	27.27	20.75	20.25	24.53	0.796
SE (%)	76.53±8.78	74.91±9.01	79.35±6.64	70.43±8.15	81.32±9.65	74.82±6.95	75.10±7.91	78.65±6.83	0.826
SL (min)	45.89±16.72	49.20±14.35	42.65±14.17	46.05±13.58	39.09±11.32	49.03±14.21	49.31±14.52	43.89±15.67	0.613
Duration(h)	10.21±1.55	10.25±1.49	10.19±1.52	10.40±1.72	9.65±1.20	10.41±1.58	10.02±1.46	10.23±1.46	0.151
<6/6–7/8–9/10(h)	6/13/183/458	2/5/86/207	3/6/78/199	1/1/14/46	0/1/5/6	2/1/44/119	2/6/50/108	0/3/46/117	0.552
Nap in daytime									
Eve/Usu/Occ/Never	186/101/80/264	84/45/37/120	78/39/36/122	19/15/6/19	5/2/1/3	53/21/23/61	41/32/16/72	48/20/21/71	0.492
MMSE scores	15.48±5.44	15.73±5.29	15.52±5.53	14.70±5.33	15.55±5.99	15.59±5.20	15.92±5.44	16.37±5.13	<0.001**
Waist circumference (cm)	76.60±9.51	72.50±8.68	78.36±7.21	87.08±8.57	87.55±11.25	71.63±7.40	73.51±9.97	78.45±6.47	0.001**
DBP	72.59±12.06	71.38±11.31	73.33±12.34	74.92±12.90	76.36±13.43	71.08±12.14	71.60±10.08	73.57±12.79	<0.001**
SBP	139.71±23.31	136.36±23.17	142.73±22.13	143.43±23.18	153.18±11.46	135.25±24.64	139.28±22.81	142.33±22.79	0.040*
TG (mmol/L)	1.22±0.64	1.12±0.45	1.22±0.71	1.57±0.83	1.65±1.06	1.12±0.45	1.14±0.48	1.19±0.56	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	4.20±0.90	4.06±0.84	4.07±0.79	<0.001**
HDL (mmol/L)	1.58±0.59	1.70±0.77	1.49±0.38	1.42±0.28	1.31±0.24	1.79±0.99	1.55±0.33	1.52±0.42	<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	2.33±1.66	2.17±0.60	2.21±0.59	0.064
FBG(mmol/L)	4.46±1.45	4.48±1.58	4.36±1.26	4.67±1.54	4.70±1.32	4.59±1.69	4.37±1.37	4.30±1.21	<0.001**
SUA (μmol/L)	318.72±87.01	303.31±90.94	327.19±80.86	350.82±89.47	334.18±77.73	299.96±94.43	304.55±79.99	333.38±84.73	0.089
Smoking habits									
Former (Yes/No)	242/395	124/167	97/179	18/40	3/7	66/92	71/92	58/104	0.242
Current (Yes/No)	361/289	166/130	155/128	34/26	6/5	88/74	98/69	89/74	<0.001**
Alcoholic									
Former (Yes/No)	379/262	172/118	166/114	38/20	3/7	90/70	99/67	92/68	0.130
Current (Yes/No)	176/473	82/213	73/210	13/47	8/3	50/111	42/125	43/121	0.771
Tea habits									
Former (Yes/No)	287/349	136/158	123/150	24/35	4/6	77/84	72/92	67/91	0.591
Current (Yes/No)	275/376	127/169	119/165	22/38	7/4	72/89	65/100	60/102	0.568

Table 2 (continued)

Characteristics	All (<i>n</i> =660)	Diagnostic criteria in BMI			Quartile of (BMI)					<i>P</i> value	
		Underweight (18.5)	Normal (18.5–23)	Overweight (23–27.5)	Obese (27.5)	<i>P</i> value	Under 16.6	16.6–18.9	18.9–21.1		Above 21.1
Exercise habits											
Former (Yes/No)	214/420	101/188	101/186	19/40	3/6	0.873	47/111	64/99	55/104	48/106	0.788
Current (Yes/No)	265/380	126/168	108/172	26/34	5/6	0.408	60/102	77/87	64/97	64/94	0.311
						0.952					0.310
						0.743					0.274

Exercise habits

Former (Yes/No)	214/420	101/188	101/186	19/40	3/6	0.873	47/111	64/99	55/104	48/106	0.788
Current (Yes/No)	265/380	126/168	108/172	26/34	5/6	0.408	60/102	77/87	64/97	64/94	0.311
						0.952					0.310
						0.743					0.274

Baseline characteristics were compared between different body mass index (BMI) groups

Poor sleep quality, *SE* sleep latency, *SE* sleep efficiency percentage (*SE*), *SUA* serum uric acid, *BMI* body mass index, *FBG* fasting blood glucose, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *TC* total cholesterol, *TG* triglyceride, *MMSE* Mini-Mental State Examination

* $P < 0.05$, ** $P < 0.01$ (using one-way analysis of variance for continuous variable and Pearson Chi-Square or Fisher's exact test (whereas an expected cell count was < 5) for categorical variables; in the testing, a P value < 0.05 was considered to be statistically significant)

In the present study, although we excluded the subjects being bedridden, or with cancer, a history or clinical evidence of stroke, terminal stage of physical disease, who had longer sleep duration, the sleep duration in the long-lived individuals was still longer than 10 h and more than 50% of them with the sleep duration longer than 10 h. This indicated the change in sleep quality with age, and this finding was consistent with that of previous reports (Ohayon et al. 2004; Redline et al. 2004). The longer sleep duration might be explained as follows: (1) they were all retired and no job to do; (2) any of the participants had underlying dementia; in the present study, there was a low mean MMSE score in the sample, and sleep quality was related with MMSE score; (3) primary sleep disorders, many of which, such as sleep apnea, restless legs syndrome, and rapid eye movement behavior disorder, tend to occur with increasing frequency in older adults.

In the present study, the differences in blood pressure, serum lipid/lipoprotein levels and SUA were all significant among the different BMI subgroups. Typically, general or central adiposity, elevated blood pressure, dyslipidemia, hyperuricemia, and hyperglycemia are thought to be part of this syndrome. The present study provided evidence from the long-lived subjects and showed that metabolic syndrome components in the long-lived subjects might be strongly correlated with each other. On the other hand, between the subjects with good and poor sleep quality, none of the difference in the other components of metabolic syndrome except obesity (including serum lipid/lipoprotein levels, FBG, SUA and blood pressure) was significant. The components of metabolic syndrome were related with sleep quality with the same mechanism (Hall et al. 2008). This indicated that in association of sleep quality with BMI, the difference between the general population and the long-lived subjects was not only from the changes in body composition with age and the changes in sleep patterns with age, but also from the metabolic changes with age.

In the present study, the lifestyles (including exercise, smoking, alcohol consumption, and so on), which had been confirmed factors related with both sleep and obesity, were not different among different BMI groups or between good and poor sleep quality groups. The association of BMI or sleep quality with these lifestyles also changes with age, the mechanism was unclear and should be further explored.

Table 3 Effect of BMI on sleep quality in long-lived subjects

Characteristics	Diagnostic criteria in BMI								Quartile of (BMI)							
	Underweight		Normal weight		Overweight		Obese		Under 16.6		16.6–18.9		18.9–21.1		Above 21.1	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Unadjusted	1.500 (0.386– 5.834)		1.182 (0.305– 4.584)		1.636 (0.373– 7.187)		1.000 (reference)		1.050 (0.610– 1.808)		1.083 (0.627– 1.871)		0.846 (0.499– 1.435)		1.000 (Reference)	
Model 1	1.561 (0.383– 6.212)		1.111 (0.278– 4.259)		1.598 (0.376– 7.412)		1.000 (reference)		1.210 (0.658– 2.213)		1.003 (0.515– 1.718)		0.801 (0.464– 1.371)		1.000 (Reference)	
Model 2	3.082 (0.679– 13.908)		2.375 (0.514– 10.003)		3.222 (0.549– 15.678)		1.000 (reference)		1.123 (0.638– 2.002)		1.167 (0.675– 2.175)		0.953 (0.562– 1.675)		1.000 (Reference)	
Model 3	2.765 (0.514– 12.789)		2.107 (0.421– 9.505)		2.784 (0.538– 13.651)		1.000 (reference)		1.228 (0.646– 2.307)		1.086 (0.597– 1.989)		0.887 (0.501– 1.623)		1.000 (Reference)	

OR odds ratio, *Unadjusted* Wald Chi-square test with $df=1$ was used, adjusted multiple logistic regression was used to adjust for covariates, *model 1* adjustment made with the other components of metabolic syndrome (waist circumference, blood pressure, serum lipid/lipoprotein, blood sugar, uric acid), *model 2* adjustment made with lifestyles (smoking habits, alcoholic, tea habits, exercise habits), *model 3* adjustment made with age, gender, nap in daytime, cognitive function and all factors above

* $P<0.05$, ** $P<0.01$

Our study had some limitations that deserve a mention. First, 870 subjects aged 90 years or older volunteered for the PLAD Study; among these 870 volunteers, only 660 had non-missing data for the two main variables involved in the current analyses. There might be selection biases. Since the many subjects excluded from the study were without the information on the two main variables, we could not compare the two main variables between the subjects included and excluded from the study, and the selection biases and its effect on the result of the study could not be confirmed. Because subjects are being bedridden or with cancer, a history or clinical evidence of stroke, terminal stage of physical disease such as respiratory system disease, cardiovascular disease, kidney disease, and so on, had longer sleep duration and poor sleep quality it was difficult to measure weight and height, and BMI could not be calculated because they were unable to stand. We excluded them. However, our sample was from community dwellers and the information from them (excluded from the study) might be unable to influence the practical implications of the

present study. Second, one of the limitations of our study was that the survey did not ask about calories consumed by the participants, and our study did not specifically identify participants with malnutrition. However, our sample was from community dwellers, 90% of participants lived in the country side, and all subjects were interviewed in home. Subjects being bedridden or with severe disease were excluded from our study. In fact, our sample was rural health longevity, who were without disorder in intake nutrition and were similar in diet habits and socioeconomic status. This might be unable to influence the practical implications of the present study. Third, in the study, sleep quality was measured using a questionnaire, not sleep studies or actigraphy, which measured quality using instrument and more sensitive and specific. However, it seemed unfeasible using this instrument in the subjects in their home. The previous study had showed the good reliability and good construct validity of PSQI in measuring sleep quality (Shochat et al. 2007). Fourth, there was a gender imbalance in our population, a common characteristic

of very old populations. Of the 870 long-living individuals (≥ 90 years) in the Dujiangyan district (2005), 444 women and 216 men were included in this study. Finally, 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, among longevity Chinese, there is no association between BMI and sleep quality, which was different from that in general population.

Acknowledgements This work was supported by the Discipline Construction Foundation of Sichuan University and by grants from the Project of Science and Technology Bureau of Sichuan Province (2006Z09-006-4), the Construction Fund for Subjects of West China Hospital of Sichuan University (XK05001) and the government of SiChuan province of China (2010FZ0061). The authors thank the staff of the Department of Geriatrics Medicine, West China Hospital and Dujiangyan Hospital, and all participants (as well as their legal proxies) for their great contribution.

References

- Bauer L, Dick D, Bierut L, Bucholz K, Edenberg H, Kuperman S, Kramer J, Nurnberger J, O'Connor S, Rice J, Rohrbaugh J, Schuckit M, Tischfield J, Porjesz B, Hesselbrock V (2010) Obesity, smoking, and frontal brain dysfunction. *Am J Addict* 19(5):391–400
- Buyse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ (1989) The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res* 28:193–213
- Chan KM, Pang WS, Ee CH, Ding YY, Choo P (1998) Self-perception of health among elderly community dwellers in Singapore. *Ann Acad Med Singapore* 27(4):461–467
- Drøystvold WB, Nilsen TI, Krüger O, Holmen TL, Krokstad S, Midthjell K, Holmen J (2006) Change in height, weight and body mass index: longitudinal data from the HUNT study in Norway. *Int J Obes Lond* 30(6):935–939
- Erik Landhuis C, Poulton R, Welch D, Hancox RJ (2008) Childhood sleep time and long-term risk for obesity: a 32-year prospective birth cohort study. *Pediatrics* 122:955–960
- Flegal KM, Carroll MD, Ogden CL, Johnson CL (2002) Prevalence and trends in obesity among US adults. 1999–2000. *JAMA* 288:1723–1727
- French MT, Norton EC, Fang H, Maclean JC (2010) Alcohol consumption and body weight. *Health Econ* 19(7):814–832
- Gangwisch JE, Malaspina D, Boden-Albala B, Heymsfield SB (2005) Inadequate sleep as a risk factor for obesity: analyses of the NHANES I. *Sleep* 28:1289–1296
- Grandner MA, Hale L, Moore M, Patel NP (2010) Mortality associated with short sleep duration: the evidence, the possible mechanisms, and the future. *Sleep Med Rev* 14(3):191–203
- Hall MH, Muldoon MF, Jennings JR, Buysse DJ, Flory JD, Manuck SB (2008) Self-reported sleep duration is associated with the metabolic syndrome in midlife adults. *Sleep* 31(5):635–643
- Horber FF, Gruber B, Thomi F, Jensen EX, Jaeger P (1997) Effect of sex and age on bone mass, body composition and fuel metabolism in humans. *Nutrition* 13:524–534
- Huang CQ, Dong BR, Zhang YL, Wu HM, Liu QX, Flaherty JH (2009a) Moderate or severe dementia and hypertension among Chinese nonagenarians and centenarians. *Hypertens Res* 32(7):554–558
- Huang CQ, Dong BR, Wu HM, Zhang YL, Wu JH, Lu ZC, Flaherty JH (2009b) Association of moderate or severe dementia with serum lipid/lipoprotein among Chinese nonagenarians and centenarians. *Dement Geriatr Cogn Disord* 27(2):111–116
- Jean-Louis G, Kripke DF, Ancoli-Israel S, Klauber MR, Sepulveda RS, Mowen MA, Assmus JD et al (2000) Circadian sleep, illumination, and activity patterns in women: influences of aging and time reference. *Physiol Behav* 68:347–352
- Karra E, Batterham RL (2010) The role of gut hormones in the regulation of body weight and energy homeostasis. *Mol Cell Endocrinol* 316(2):120–128
- Keith SW, Redden DT, Katzmarzyk PT, Boggiano MM, Hanlon EC, Benca RM, Ruden D, Pietrobelli A, Barger JL, Fontaine KR, Wang C, Aronne LJ, Wright SM, Baskin M, Dhurandhar NV, Lijoi MC, Grilo CM, Deluca M, Westfall AO, Allison DB (2006) Putative contributors to the secular increase in obesity: exploring the roads less traveled. *Int J Obes* 30:1585–1594
- Lamberg L (2006) Rx for obesity: eat less, exercise more, and maybe get more sleep. *JAMA* 295:2341–2344
- Lau EM, Lynn HS, Woo JW, Kwok TC, Melton LJ 3rd (2005) Prevalence of and risk factors for sarcopenia in elderly Chinese men and women. *J Gerontol A Biol Sci Med Sci* 60(2):213–216
- Littman AJ, Vitiello MV, Foster-Schubert K, Ulrich CM, Tworoger SS, Potter JD, Weigle DS, Mctiernan A (2006) Sleep, ghrelin, leptin and changes in body weight during a 1-year moderate-intensity physical activity intervention. *Int J Obes* 31:466–475
- Lopez-Garcia E, Faubel R, Leon-Munoz L, Zuluaga MC, Banegas JR, Rodriguez-Artalejo F (2008) Sleep duration, general and abdominal obesity, and weight change among the older adult population of Spain. *Am J Clin Nutr* 87:310–316
- Nevitt MC, Cummings SR, Kidd S, Black D (1989) Risk factors for recurrent nonsyncopal falls. A prospective study. *JAMA* 261:2663–2668
- Ohayon MM, Carskadon MA, Guilleminault C, Vitiello MV (2004) Meta-analysis of quantitative sleep param from childhood to old age in healthy individuals: developing normative sleep values across the lifespan. *Sleep* 27:1255–1273
- Patel SR, Hu FB (2008) Short sleep duration and weight gain: a systematic review. *Obesity* 16:643–653

- Rao MN, Blackwell T, Redline S, Stefanick ML, Ancoli-Israel S (2009) Osteoporotic fractures in men (MrOS) study group. Association between sleep architecture and measures of body composition. *Sleep* 32(4):483–490
- Redline S, Kirchner HL, Quan SF, Gottlieb DJ, Kapur V, Newman A (2004) The effects of age, sex, ethnicity, and sleep-disordered breathing on sleep architecture. *Arch Intern Med* 164:406–418
- Scholtens S, Brunekreef B, Visscher TL, Smit HA, Kerkhof M, de Jongste JC, Gerritsen J, Wijga AH (2007) Reported versus measured body weight and height of 4-year-old children and the prevalence of overweight. *Eur J Public Health* 17(4):369–374
- Shinba T, Murashima YL, Yamamoto K (1994) Alcohol consumption and insomnia in a sample of Japanese alcoholics. *Addiction* 89(5):587–591
- Shochat T, Tzischinsky O, Oksenberg A, Peled R (2007) Validation of the Pittsburgh sleep quality index Hebrew translation (PSQI-H) in a sleep clinic sample. *Isr Med Assoc J* 9:853–856
- Snijder MB, van Dam RM, Visser M, Seidell JC (2006) What aspects of body fat are particularly hazardous and how do we measure them? *Int J Epidemiol* 35:83–92
- Spiegel K, Leproult R, Van Cauter E (1999) Impact of sleep debt on metabolic and endocrine function. *Lancet* 354:1435–1439
- Spiegel K, Tasali E, Penev P, Van Cauter E (2004) Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels and increased hunger and appetite. *Ann Intern Med* 141:846–850
- Van Cauter E, Knutson KL (2008) Sleep and the epidemic of obesity in children and adults. *Eur J Endocrinol* 159(Suppl 1):S59–S66
- Vgontzas AN (2008) Does obesity play a major role in the pathogenesis of sleep apnoea and its associated manifestations via inflammation, visceral adiposity, and insulin resistance? *Arch Physiol Biochem* 114(4):211–223
- Wang Q, Hassager C, Ravn P, Wang S, Christiansen C (1994) Total and regional body-composition changes in early postmenopausal women: age-related or menopause-related? *Am J Clin Nutr* 60:843–848
- WHO Expert Consultation (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 363(9403):157–163
- Zamboni M, Armellini F, Harris T et al (1997) Effects of age on body fat distribution and cardiovascular risk factors in women. *Am J Clin Nutr* 66:111–115
- Zee PC, Turek FW (2006) Sleep and health: everywhere and in both directions. *Arch Intern Med* 166(16):1686–1688
- Zisberg A, Nurit GY, Tamar S (2010) Contribution of routine to sleep quality in community elderly. *Sleep* 33(4):509–514