Association of possible sarcopenia, sarcopenia and sarcopenic obesity with multimorbidity among middle-aged and older adults: Findings from the China health and retirement longitudinal study

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Abstract

Background: The association between possible sarcopenia, sarcopenia and sarcopenic obesity on multimorbidity risk remains poorly investigated.

Objective: We aimed to evaluate the associations between possible sarcopenia, sarcopenia and sarcopenic obesity on multimorbidity prevalence and incidence in middle-aged and older Chinese population.

Methods: A total of 13,036 participants from the China Health and Retirement Longitudinal Study 2011 were included in cross-sectional analyses. 5,771 participants were including in longitudinal analyses and were followed up in 2018. Sarcopenia status was defined according to the Asian Working Group for Sarcopenia 2019 (AWGS 2019) criteria. Obesity was defined according to body mass index.

Results: In cross-sectional analyses, possible sarcopenia, sarcopenia and sarcopenic obesity were significantly associated with higher multimorbidity prevalence. During the 7 years of follow-up, 2295(39.77%) participants with new-onset multimorbidity were identified. Compared with participants without sarcopenia or obesity, a greater increase in the risk of multimorbidity incidence was found among participants with obesity only (OR=1.39, 1.21-1.59), sarcopenia only (OR=1.45, 1.35-1.58) and sarcopenic obesity (OR=2.42, 2.03-2.89). Both pre-sarcopenia, sarcopenia and sarcopenic obesity were positively related to an increased number of morbidities.

Conclusions: Pre-sarcopenia, sarcopenia and sarcopenic obesity were associated with higher multimorbidity prevalence and incidence. Our findings provide important implications for screening and preventing possible sarcopenia, sarcopenia and obesity, which may be beneficial in reducing chronic disease burden.

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Association of possible sarcopenia, sarcopenia and sarcopenic obesity with multimorbidity among middle-aged and older adults: Findings from the China health and retirement longitudinal study

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Abstract

Background and objectives: The association between possible sarcopenia, sarcopenia and sarcopenic obesity on multimorbidity risk remains poorly investigated. We aimed to evaluate the associations between possible sarcopenia, sarcopenia and sarcopenic obesity on multimorbidity prevalence and incidence in middle-aged and older Chinese population.

Methods: A total of 13,036 participants from the China Health and Retirement Longitudinal Study 2011 were included in cross-sectional analyses. 5,771 participants were including in longitudinal

analyses and were followed up in 2018. Sarcopenia status was defined according to the Asian Working Group for Sarcopenia 2019 (AWGS 2019) criteria. Obesity was defined according to body mass index.

Results: In cross-sectional analyses, possible sarcopenia, sarcopenia and sarcopenic obesity were significantly associated with higher multimorbidity prevalence. During the 7 years of follow-up, 2295(39.77%) participants with new-onset multimorbidity were identified. Compared with participants without sarcopenia or obesity, a greater increase in the risk of multimorbidity incidence was found among participants with obesity only (OR=1.39, 1.21-1.59), sarcopenia only (OR=1.45, 1.35-1.58) and sarcopenic obesity (OR=2.42, 2.03-2.89). Both pre-sarcopenia, sarcopenia and sarcopenic obesity were positively related to an increased number of morbidities.

Conclusion: Pre-sarcopenia, sarcopenia and sarcopenic obesity were associated with higher multimorbidity prevalence and incidence. Our findings provide important implications for screening and preventing possible sarcopenia, sarcopenia and obesity, which may be beneficial in reducing chronic disease burden.

Keywords: Sarcopenia; Possible sarcopenia; sarcopenic obesity; Multimorbidity

1. Introduction

With the growing ageing population and increasing life expectancy, multimorbidity has being an increasingly serious public health challenge[1,2]. Multimorbidity, commonly defined as the co-occurrence of at least two chronic conditions in the same individual, was reported associated with an increased risk of hospitalization, institutionalization, disability, poor health-related quality of life and all-cause mortality[3-5]. Evidence from recent studies reported that the prevalence of multimorbidity ranged from 3.5% to 100% for older adults around the world[2,6]. In China, systematic reviews reported that the overall prevalence of multimorbidity among older adults widely ranged from 6.4% to 86.9%[7].

Sarcopenia, a progressive and generalized skeletal muscle disorder involving the accelerated loss of muscle mass and function, naturally occurs in ageing, and was associated with chronic non-communicable diseases (NCDS) such as cardiovascular disease (CVD), chronic obstructive pulmonary disease, chronic liver disease and et al[8-11]. Furthermore, the new concept of sarcopenic obesity, a co-occurrence of low muscle and excess body fat, is currently being studied[12,13]. The combined conditions of sarcopenia and obesity may contribute to negative synergism in the

pathophysiology of both physical and metabolic dysfunctions. A nationwide cross-sectional study from Korea National Health and Nutritional Examination Survey (KNHANES, 2008-2011) indicated that both sarcopenia and abdominal obesity are associated with increased risk of multimorbidity, and sarcopenic obesity showed a greater risk of multimorbidity than sarcopenia or obesity alone[14]. However, the longitudinal association between sarcopenic obesity and multimorbidity has not been explored in previous study.

In 2019, the Asian Working Group for Sarcopenia (AWGS) combined the muscle mass, muscle strength, and physical performance to redefined the sarcopenia (including possible sarcopenia, sarcopenia and severe sarcopenia), and first presented the concept of possible sarcopenia in order to early stratify and identify sarcopenia risk[15]. Several studies described possible sarcopenic obesity as a risk factor for disability, CVD and all-cause mortality[9,16,17]. However, limited evidence currently exists specific to the association between possible sarcopenia, sarcopenic (including possible sarcopenia) obesity and multimorbidity risk, especially from the longitudinal cohort study.

Therefore, in current study, we aimed to conduct a cross-sectional and longitudinal analyses to investigate the associations between of possible sarcopenia, sarcopenia and sarcopenic obesity with multimorbidity risk, using data from the China Health and Retirement Longitudinal Study (CHARLS).

2. Methods

2.1 Study population

The CHARLS is an ongoing nationally representative and population-based study, that uses a multistage clustering sample method to select participants and conducted to collect a series of data regarding demographics, economic status, social networks, physical and psychological health in China[18]. The first visit was accomplished in 2011-2012 (Wave 1) of 17,708 patients, subsequently third follow-up visits carried out after that, each nearly two years apart among survivors (2013–2014:

Wave 2, 2015–2016: Wave 3 and 2017–2018: Wave 4)[18].

In current study, we conducted a cross-sectional and a longitudinal analysis using data from the four waves of CHARLS (from 2011 to 2018)[19]. In the cross-sectional analysis, we included participants according to the following criteria: (1) individuals ≥45 years old, (2) individuals with complete information about sarcopenia and multimorbidity in 2011. A total of 13,036 participants were included (Figure 1). In the longitudinal analysis, we further included participants according to the following criteria: (1) individuals without multimorbidity in baseline, (2) individuals with complete information about multimorbidity in follow-up, (3) individuals who were successfully followed-up. Finally, a total of 5,771 individuals without multimorbidity at baseline were eligible for subsequent analysis (Figure 1)[19].

2.2 Assessment of sarcopenia status and obesity

The handgrip strength (kg) was measured in the dominant hand and non-dominant hand, with the participant squeezing a YuejianTM WL-1000 dynamometer (Nantong Yuejian Physical Measurement Instrument Co., Ltd., Nantong, China) as hard as possible[20]. The cut-off points for low grip strength for men and women were <28 and <18 kg, respectively[21]. The muscle mass was estimated by the appendicular skeletal muscle mass (ASM) using a previously validated anthropometric equation in a Chinese population[22], and the ASM/Ht^2 values of <5.63 kg/m^2 in women and <7.05 kg/m^2 in men were considered as low muscle mass[20]. For physical performance, the gait speed and the chair stand test were performed to evaluate individuals' physical performance. The detail about sarcopenia evaluation and definition in CHARLS study has been described in previous study[22].

Sarcopenia status in current study was assessed according to the recommended diagnostic algorithm of AWGS 2019[15]. Sarcopenia is diagnosed when low muscle mass plus low muscle strength or low physical performance. When low muscle strength, low muscle mass and low physical performance are all detected, severe sarcopenia will be considered. Possible sarcopenia is defined by

low muscle strength with or without reduced physical performance[20].

Body mass index (BMI) was calculated by dividing weight in kilograms by height in meters squared. Obesity was defined as BMI ≥28 kg/m^2 according to Chinese criteria[23].

2.3 Definition of chronic diseases and multimorbidity

Multimobidity was defined by the coexistence of two or more of these 14 chronic conditions in the same individual. Participants without any chronic disease or with only one chronic disease were classified into non-multimorbidity group[24]. Heart disease, stroke, chronic lung disease, asthma, kidney disease, liver disease, digestive disease, cancer, psychiatric disease, memory-related disease (including dementia, Parkinson's disease, and cereal atrophy), and arthritis were defined by self-reported physician diagnosis[24]. Blood pressure was measured three times and hypertension was assessed as mean systolic blood pressure (SBP) ≥140 mmHg, and/or mean diastolic blood pressure (DBP) ≥ 90 mmHg, and/or using anti-hypertensive drugs[24]. Venous blood samples were also collected from each participant to obtain levels of blood glucose and glycated hemoglobin (HbA1c). Diabetes was diagnosed as meeting any of following criteria: fasting plasma glucose ≥7.0 mmol/L, random plasma glucose ≥11.1 mmol/L, or using glucose-lower drugs/insulin treatment. Dyslipidemia was defined as triglycerides ≥150 mg/dl, TC≥240 mg/dl, HDL-C <40 mg/dl, LDL-C ≥160 mg/dl, current use of the lipid-lowering medications, or self-reported history of dyslipidemia[24].

2.4 Covariates assessments

The covariates were collected at baseline including age, sex, place of residence (rural vs. urban), smoking status (ever smoking vs. never smoking), educational level (illiteracy; primary school; middle school; high school or above), drinking status (ever drinking vs. never drinking), marriage status and family's economic status (≥average level or < average level, which was assessed by the individuals' standard of living)[20].

2.5 Statistical analyses

In present study, only 457 (3.51%) participants and 145 (2.51%) participants had severe sarcopenia in cross-sectional and longitudinal analyses. Thus, we merged those with severe sarcopenia into sarcopenia group[20]. Participants' baseline characteristics are presented as percentages for categorical variables, as the means with standard deviation for normally distributed continuous variables and as medians with interquartile range for non-normally distributed variables. Demographic and clinical characteristics were compared by T-test or Kruskal-Wallis test for continuous variables and χ^2 test for categorical variables among participants with or without sarcopenia[20].

In cross-sectional and longitudinal analyses, multivariable logistic regression models were applied to calculate the odds ratio (OR) and 95% confidence interval (95% CI) between sarcopenia (yes vs no), sarcopenia status (sarcopenia vs pre-sarcopenia vs no), sarcopenic obesity status (sarcopenic obesity vs sarcopenia only vs obesity only vs no) with the risk of multimorbidity[20]. A Poisson regression model with quasi- likelihood estimation was applied to examine whether sarcopenia, sarcopenia status and sarcopenic obesity status could increase the number of morbidities. Furthermore, we explored the associations between sarcopenia, sarcopenia status and sarcopenic obesity status with risk of 14 chronic diseases separately[20].

In the longitudinal analysis, subgroup analyses were performed to evaluate the association between sarcopenic obesity status and the risk of multimorbidity according to sex, age, place of residence, smoking, drinking and family's economic status. Two tailed $P<0.05$ was considered statistical significance. All statistical analyses were conducted using SAS statistical software (version 9.4, Cary, NC).

3. Results

3.1 Characteristics of participants in the cross-sectional study

In the current cross-sectional study, a total of 13,036 participants (6,226 men and 6,810 women) were included in the cross-sectional analysis, and the average age was 59.19±9.60 years. Among the 13,036 participants, the prevalence of possible sarcopenia and sarcopenia was 22.91% and 14.11%, respectively. Compared to participants without sarcopenia, those with sarcopenia were more likely to be older, females, be unmarried, living in rural areas, with lower educational level, had lower level of smoking and drinking, and had higher BMI (Table 1).

A total of 5,771 participants (6,226 men and 6,810 women) were included in the longitudinal analysis, and the average age was 57.45±8.87 years. Among the them, the prevalence of possible sarcopenia and sarcopenia was 19.65% and 11.28%, respectively. Table S1 shows the characteristics of the 5,771 participants according to sarcopenia status.

3.2 Cross-sectional associations of sarcopenia, sarcopenia status and sarcopenic obesity status with multimorbidity prevalence and chronic conditions

In the cross-sectional study of 13,036 participants, the overall prevalence of chronic multimorbidity was 39.20%. Table 2 shows the associations of sarcopenia, sarcopenia status and sarcopenic obesity status with sarcopenia prevalence. Compared to participants without sarcopenia, those with sarcopenia had higher prevalence of multimorbidity with the corresponding OR (95%CI) was 1.33(1.23-1.43), after controlling for the potential confounders. When participants were divided into three subgroups (no; pre-sarcopenia; sarcopenia), the estimates for the association of individuals with pre-sarcopenia or sarcopenia were 1.53(1.40-1.68) and 1.18(1.05-1.32), respectively. Examination of the unadjusted effects of sarcopenia, obesity, and sarcopenic obesity on the risk of multimorbidity compared with the normal group showed that there was a substantial elevated risk of multimorbidity in participants with obesity only (OR=1.39, 1.21-1.59), sarcopenia only (OR=1.45, 1.35-1.58) and sarcopenic obesity (OR=2.42, 2.03-2.89). The significant association of sarcopenia only, sarcopenic obesity with increased risk of multimorbidity remained after full adjustment with all

covariates (Table 2). After controlling for covariates, we found that individuals with sarcopenic obesity was significantly associated with increased risks of most chronic diseases except for cancer with the adjusted ORs from 1.29(1.05-1.59) for hypertension to 4.12(2.76-6.15) for stroke (Table S2). The Poisson regression results showed that both pre-sarcopenia, sarcopenia and sarcopenic obesity were positively related to an increased number of morbidities (Table 4).

3.3 Longitudinal association between sarcopenia, sarcopenia status and sarcopenic obesity status with new-onset multimorbidity

From 2011 to 2018, a total of 2295(39.77%) participants with new-onset multimorbidity were identified. Table 3 shows the relationship between pre-sarcopenia, sarcopenia status and sarcopenic obesity status with new-onset multimorbidity. After adjusting for all covariates, individuals with pre-sarcopenia, sarcopenia and sarcopenic obesity were more likely to have new onset multimorbidity. As shown in Figure 2, individuals with sarcopenic obesity were more likely to have a higher risk of dyslipidemia (OR=2.15, 1.53-3.02), diabetes (OR=2.89, 1.95-4.27), heart disease (OR=2.44, 1.70-3.49), stroke (OR=2.34, 1.41-3.88), cancer (OR=2.48, 1.10-5.60), digestive disease (OR=1.85, 1.21-2.81), arthritis and memory-related disease (OR=2.10, 1.02-4.29). Similarly, the Poisson regression results showed that both pre-sarcopenia, sarcopenia and sarcopenic obesity were positively related to an increased number of morbidities in longitudinal study (Table 4).

In the subgroup analysis, the significant associations between sarcopenic obesity with risk of new-onset multimorbidity were observed in all subgroups (Table 5). There was a significant interaction between sarcopenic obesity and living place or family's economic status, in relation to risk of primary outcome (*p* for interaction<0.05)

4. Discussion

In this nationwide longitudinal prospective cohort study of Chinese adults aged 45 years and

above, we first demonstrated that pre-sarcopenia, sarcopenia and sarcopenic obesity were independently associated with the prevalence of multimorbidity in the cross-sectional analysis, and were associated with increased risk of new-onset multimorbidity in longitudinal prospective cohort study. Furthermore, both pre-sarcopenia, sarcopenia and sarcopenic obesity were positively related to an increased number of morbidities. Moreover, the longitudinal observations remain consistent when stratified by sex, age, place of residence, smoking, drinking and family's economic status.

Studies on associations between sarcopenia and individuals' chronic disease had been reported in post decades. Evidence from cross-sectional and longitudinal prospective cohort study indicated sarcopenia was a risk factor for CVD, chronic obstructive pulmonary disease, chronic liver disease, hypertension, asthma, heart failure and other chronic diseases[8-12,25,26]. Therefore, sarcopenia may have harmful effects on the multimorbidity risk. Hu et al. using data from CHARLS and the Study on global AGEing and adult health (SAGE) found the presence of sarcopenia (OR=5.76, 2.01-16.50) was positively associated with the prevalence of chronic obstructive pulmonary disease[8]. Findings from the cross-sectional KNHANES 2008-2011 study suggested that sarcopenia was independently associated with increased risk of multimorbidity[14]. In consistent with previous studies, our results indicated sarcopenia not only associated with multimorbidity prevalence and number of morbidities in cross-sectional study, but also associated with multimorbidity incidence and number of morbidities in longitudinal prospective cohort study. Although the major criteria of possible sarcopenia have not been proposed for a long time, several studies had reported possible sarcopenia was an independent predictor of chronic diseases[9,16,17]. Our finding supported the validity of criteria of possible sarcopenia by the AWGS 2019, and suggested that individuals with possible sarcopenia had a 53% and 19% increased risk of multimorbidity prevalence and incidence. To the best of our knowledge, the current study was the first study to evaluate the relationship between possible sarcopenia and multimorbidity risk.

Although the universally recognized diagnostic criteria for sarcopenic obesity was not

agreed[27], the sarcopenic obesity is appropriately characterized as a confluence of two epidemics -an ageing population and rising obesity rates[28]. Evidence from NHANES (National Health and Nutrition Examination Survey) shown that the prevalence of sarcopenic obesity were 12.6% in men and 33.5% in women[29]. In another cohort of individuals from South Korea's Korean Sarcopenic Obesity Study, the reported prevalence of sarcopenic obesity of healthy volunteers aged 20–80 years ranged from 1.3–15.4% in men to 0.8–22.3% in women[30]. In current study, the corresponding prevalence of sarcopenic obesity was 4.13% and 2.98% in cross-sectional and longitudinal prospective cohort analysis, which was consistent with prevalence in South Korea. Several previous studies had reported associations of sarcopenic obesity with chronic health conditions, including disability[31], metabolic impairments[32], comorbidities[27] and all-cause mortality[33]. Several cross-sectional earlier studies have confirmed the association between sarcopenic obesity and insulin resistance, adverse glucose metabolism, dyslipidemia, hypertension, metabolic syndrome and CVD compared to sarcopenia or obesity alone[32,34-37]. In addition, data from the Fourth Thai National Health Examination Survey (NHES-IV) suggested that BMI combined with possible sarcopenia severity is a better predictor of mortality risk than either parameter alone[16]. Furthermore, An KO et al found a greater increase in the risk of multimorbidity among individuals with sarcopenic obesity compared with either sarcopenia or obesity alone[14]. The present study provides a more valid appraisal of the relationship between possible sarcopenic obesity, sarcopenic obesity with multimorbidity prevalence and progression of multimorbidity. Our results also indicated that sarcopenic obesity are involved in the development of individual diseases such as dyslipidemia, diabetes, heart disease, stroke, cancer, digestive disease, arthritis and memory-related disease. All the evidence proved that the combination of sarcopenia (including possible sarcopenia) and obesity may give rise to greater and synergistic harmful effects on chronic disease and multimorbidity.

With the progression of physiological aging, our body composition changes, including loss of muscle mass and the accumulation of body fat, and the presence of concurrent environmental

obesogenic factors and physical illnesses[38]. Both obesity and sarcopenia is a hyper-inflammation status and associated with muscle mitochondrial dysfunction, which may produce reactive oxygen species through oxidative stress, thus damaging vascular endothelium and cardiomyocytes[39,40]. Sarcopenic obesity is also with insulin resistance and multiple metabolic disorders, which may increase functional limitation and metabolic diseases[41,42]. Furthermore, the decline in muscular strength and function by age-related skeletal muscle loss and weight gain may influence the physical dysfunction[43]. Further studies are needed to clarify this potential mechanism.

Lifestyle interventions, including calorie restriction and physical activity, are recommended to intervene sarcopenic obesity[27]. Dennis Villareal's work suggested that weight loss alone or exercise alone improved physical function, and a combination of weight loss and regular exercise improved physical function and ameliorated frailty more than either intervention alone[44]. In a pilot study, participants with sarcopenic obesity undergoing a weight loss programme augmented by a high-protein diet showed improvements in muscle strength and Short Form-36 scores[45]. However, findings have not always been consistent in available randomized controlled trials[27]. Further studies are also warranted to explore more effective interventions.

The current study has several strengths. First, the study was based on the data from the CHARLS study, which is a large nationally representative cohort study with a high response rate, and potential confounders were collected and controlled in the multivariable models. Second, unlike previous studies, this is the first to assess the potential relationships between possible sarcopenia, sarcopenia and sarcopenic obesity on multimorbidity prevalence and incidence. Our findings together with previous studies support the importance of screening for possible sarcopenia, sarcopenia and sarcopenic obesity in general population and those with preexisting diseases. Thus, it is of clinical interest for clinicians to screen for possible sarcopenia, sarcopenia and obesity as an effective tool for early risk stratification of multimorbidity. Several potential limitations of present study need to be mentioned. First, the present study used observational data from CHARLS.

Although, we had adjusted a series of confounders. This observational analysis could be influenced by potential biases and confounding factors. Second, the CHARLS study was exclusively a Chinese population aged 45 years and older. Thus, the findings from our study might not be generalizable to other populations or younger individuals. Third, some of the participants were excluded from analysis due to incomplete sarcopenia or outcome data.

In conclusion, our findings demonstrated that both possible sarcopenia, sarcopenia and sarcopenic obesity was associated with increased risk of multimorbidity prevalence and incidence. Our findings provide more valid evidence for screening and preventing possible sarcopenia, sarcopenia and obesity, which may be beneficial in reducing the incidence and disease burden of multimorbidity. Further longitudinal studies may be needed to examine the causal association from our findings.

Declarations

Ethics approval and consent to participate

The ethics application for collecting data on human subjects in CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all CHARLS participants provided written informed consent. The details of the CHARLS data are available at its website (http://charls.pku.edu.cn/en).

Consent for publication

Not applicable.

Availability of data and materials

This analysis uses data or information from the Harmonized CHARLS dataset and Codebook, Version C as of April 2018 developed by the Gateway to Global Aging Data.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Xiaowei Zheng conceived and designed the research; Wenyan Wu and Tao Ma wrote the manuscript; and Wenyan Wu and Tao Ma the data analysis. All authors reviewed the manuscript.

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Table 1. Baseline characteristics of the study participants according to sarcopenia status in cross-sectional study (N=13036).

	Total	Sarcopenia		*P value*
		No	Yes*	
No. of subjects	13036	8211	4825	
Age, years	59.19±9.60	56.93±8.43	62.99±10.24	<0.001
Sex, n (%)				<0.001
Male	6226(47.76)	4183(50.94)	2043(42.34)	
Female	6810(52.24)	4028(49.06)	2782(57.66)	
Marital status				<0.001
Married	11082(85.01)	7255(88.36)	3827(79.32)	
Unmarried	1954(14.99)	956(11.64)	998(20.68)	
Living place, n (%)				<0.001
Urban	4822(36.99)	3194(38.92)	1626(33.70)	
Rural	8214(63.01)	5016(61.08)	3199(66.30)	
Family's economic status, n (%)				0.889
<Average level	6518(50)	4844(58.99)	2851(59.09)	
≥Average level	6518(50)	3367(41.01)	1974(40.91)	
Education level, n (%)				<0.001
Illiteracy	3721(28.54)	1835(22.35)	1886(39.09)	
Primary school	5270(40.43)	3311(40.32)	1959(40.60)	
Middle school	2639(20.24)	1965(23.93)	674(13.97)	
High school or above	1406(10.79)	1100(23.28)	268(12.64)	
Smoking, n (%)	5225(40.08)	3429(41.76)	1786(37.02)	<0.001
Drinking, n (%)	5083(38.99)	3418(41.63)	1665(34.61)	<0.001
BMI (kg/m^2)	23.47±3.95	23.68±3.86	23.09±4.06	<0.001

Continuous variables are expressed as mean± standard deviation, or as median (interquartile range). Categorical variables are expressed as frequency (percent).

* Pre-sarcopenia were included sarcopenia.

Table 2. Association of sarcopenia status, obesity with multimorbidity prevalence in cross-sectional study (N=13036).

	Case, n (%)	Model 1	Model 2	Model 3
Sarcopenia				
No	2932(35.71)	1.00(Ref)	1.00(Ref)	1.00(Ref)
Yes	2178(45.14)	1.48(1.38-1.59)	1.33(1.23-1.44)	1.33(1.23-1.43)
Sarcopenia status				
No	2932(35.71)	1.00(Ref)	1.00(Ref)	1.00(Ref)
Pre-sarcopenia	1395(46.72)	1.58(1.45-1.72)	1.41(1.29-1.54)	1.53(1.40-1.68)
Sarcopenia	783(42.58)	1.34(1.21-1.48)	1.17(1.04-1.32)	1.18(1.05-1.32)
Combined effect of sarcopenia and obesity				
No	2536(34.83)	1.00(Ref)	1.00(Ref)	1.00(Ref)
Obesity only	396(42.58)	1.39(1.21-1.59)	1.17(0.99-1.40)	1.17(0.98-1.39)
Sarcopenia only*	1874(43.72)	1.45(1.35-1.58)	1.37(1.26-1.48)	1.30(1.19-1.41)
Sarcopenic obesity*	304(56.40)	2.42(2.03-2.89)	1.99(1.63-2.44)	1.88(1.53-2.31)

* Pre-sarcopenia were included sarcopenia.

Model 1: crude model.

Model 2: adjusted for age, sex, BMI, educational level, marriage status, family's economic status.

Model 3: further adjusted for cigarette smoking, alcohol consumption, and residential locations based on Model 2.

Table 3. Association of sarcopenia status, obesity with new-onset multimorbidity in longitudinal study (N=5771).

	Case, n (%)	Model 1	Model 2	Model 3
Sarcopenia				
No	1527(38.31)	1.00(Ref)	1.00(Ref)	1.00(Ref)
Yes*	768(43.03)	1.22(1.09-1.36)	1.15(1.02-1.29)	1.14(1.01-1.29)
Sarcopenia status				
No	1527(38.31)	1.00(Ref)	1.00(Ref)	1.00(Ref)
Pre-sarcopenia	487(42.95)	1.21(1.06-1.39)	1.12(0.98-1.28)	1.19(1.04-1.36)
Sarcopenia	281(43.16)	1.22(1.03-1.45)	1.33(1.10-1.61)	1.31(1.04-1.55)
Combined effect of sarcopenia and obesity				
No	1325(37.18)	1.00(Ref)	1.00(Ref)	1.00(Ref)
Obesity only	202(47.87)	1.55(1.27-1.90)	1.54(1.26-1.89)	1.57(1.28-1.93)
Sarcopenia only*	678(42.03)	1.23(1.09-1.38)	1.17(1.03-1.33)	1.15(1.01-1.30)
Sarcopenic obesity	90(52.33)	1.86(1.37-2.52)	1.80(1.32-2.46)	1.76(1.29-2.40)

* Pre-sarcopenia were included sarcopenia.

Model 1: crude model.

Model 2: adjusted for age, sex, BMI, educational level, marriage status, family's economic status.

Model 3: further adjusted for cigarette smoking, alcohol consumption, and residential locations based on Model 2.

Table 4. The association of sarcopenia status, obesity with the number of morbidities in cross-sectional and longitudinal study.

	Crude model (β (95 %CI))	Adjusted model (β (95 %CI))
Cross-sectional study (N=13036)		
Sarcopenia		
No	1.00(Ref)	1.00(Ref)
Yes[#]	0.085(0l056-0.115)[*]	0.075(0.044-0.106)[*]
Sarcopenia status		
No	1.00(Ref)	1.00(Ref)
Pre-sarcopenia	0.097(0.064-0.131)[*]	0.090(0.055-0.124)[*]
Sarcopenia	0.065(0.022-0.106)[*]	0.043(0.002-0.089)[*]
Combined effect of sarcopenia and obesity		
No	1.00(Ref)	1.00(Ref)
Obesity only	0.085(0.030-0.141)[*]	0.081(0.025-0.137)[*]
Sarcopenia only[#]	0.083(0.051-0.114)[*]	0.071(0.037-0.104)[*]
Sarcopenic obesity[#]	0.184(0.122-0.247)[*]	0.173(0.110-0.237)[*]
Longitudinal study (N=5771)		
Sarcopenia		
No	1.00(Ref)	1.00(Ref)
Yes[#]	0.092(0.023-0.161)[*]	0.080(0.008-0.152)[*]
Sarcopenia status		
No	1.00(Ref)	1.00(Ref)
Pre-sarcopenia	0.123(0.033-0.193)[*]	0.106(0.026-0.187)[*]

Sarcopenia	0.054(0.020-0.158)*	0.043(0.009-0.132)*
Combined effect of sarcopenia and obesity		
No	1.00(Ref)	1.00(Ref)
Obesity only	0.124(0.003-0.246)*	0.132(0.010-0.254)*
Sarcopenia only#	0.086(0.012-0.160)*	0.007(-0.004-0.150)*
Sarcopenic obesity#	0.263(0.100-0.426)*	0.257(0.093-0.421)*

Adjusted for age, sex, BMI, educational level, marriage status, family's economic status, cigarette smoking, alcohol consumption, and residential locations.

*P<0.005; #Pre-sarcopenia were included sarcopenia.

Table 5. Subgroup analysis of ORs (95% CI) of sarcopenia status, obesity with new-onset multimorbidity in longitudinal study.

Characteristics	No	Obesity only	Sarcopenia only*	Sarcopenic obesity*	*P* value	*P*-$_{interaction}$
Sex						
Male	1.00(Ref)	1.12(0.93-1.35)	1.63(0.87-3.04)	1.76(1.26-2.46)	0.045	0.492
Female	1.00(Ref)	1.49(1.15-1.94)	1.18(0.99-1.39)	1.83(1.28-2.62)	0.001	
Age, years						
<60	1.00(Ref)	1.97(1.02-3.80)	1.29(1.01-1.67)	2.07(1.02-4.18)	0.017	0.273
≥60	1.00(Ref)	1.57(1.26-1.95)	1.13(0.98-1.31)	1.70(1.20-2.40)	0.001	
Living place						
Urban	1.00(Ref)	1.15(0.71-1.87)	1.29(1.02-1.63)	1.66(1.20-2.29)	<0.001	0.018
Rural	1.00(Ref)	1.53(1.17-2.00)	1.09(0.94-1.27)	2.45(1.61-3.71)	0.003	
Smoking						
No	1.00(Ref)	1.50(1.17-1.91)	1.14(0.97-1.34)	1.86(1.31-2.64)	0.002	0.630
Yes	1.00(Ref)	1.16(0.95-1.43)	1.41(0.73-2.74)	1.82(1.24-2.68)	<0.001	
Drinking						
No	1.00(Ref)	1.62(1.26-2.07)	1.22(1.04-1.43)	1.67(1.16-2.40)	<0.001	0.572
Yes	1.00(Ref)	1.55(1.08-2.22)	1.04(0.84-1.27)	2.22(1.20-4.12)	0.126	
Family’s economic status						
<Average level	1.00(Ref)	1.43(1.04-1.98)	1.65(1.21-3.35)	1.94(1.40-4.05)	<0.001	0.019
≥Average level	1.00(Ref)	1.11(0.96-1.27)	1.55(1.26-1.92)	1.83(1.26-1.92)	<0.001	

* Pre-sarcopenia were included sarcopenia.

In the multivariate models, confounding factors such age, sex, BMI, educational level, marriage status, family's economic status, cigarette smoking, alcohol consumption, and residential locations were included unless the variable was used as a subgroup variable.

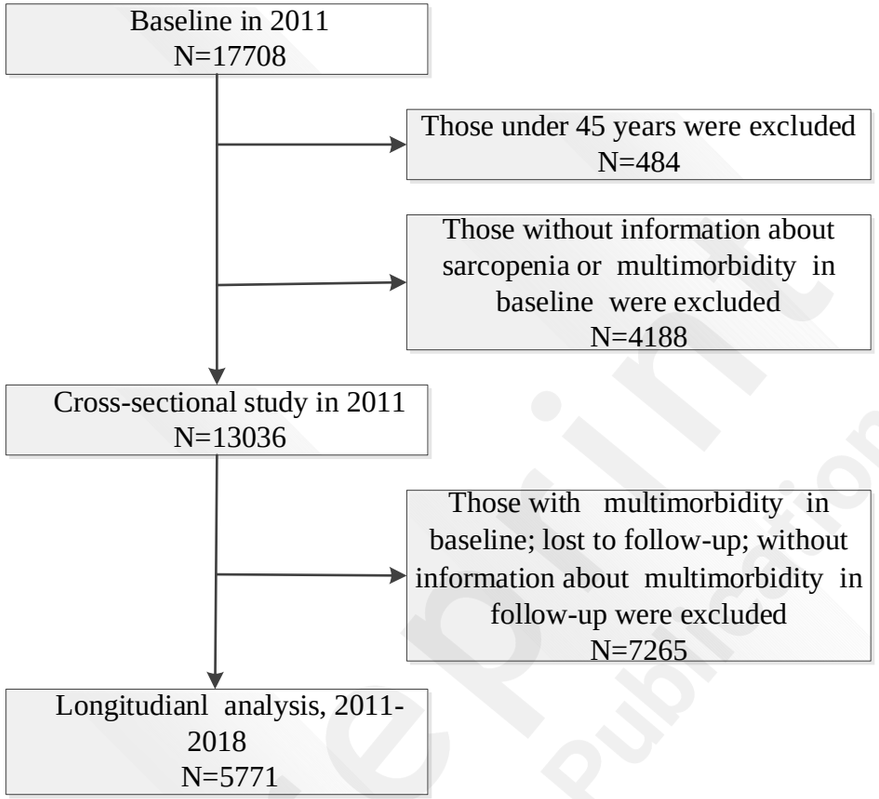

Figure 1. Flow chart of sample selection and the exclusion criteria.

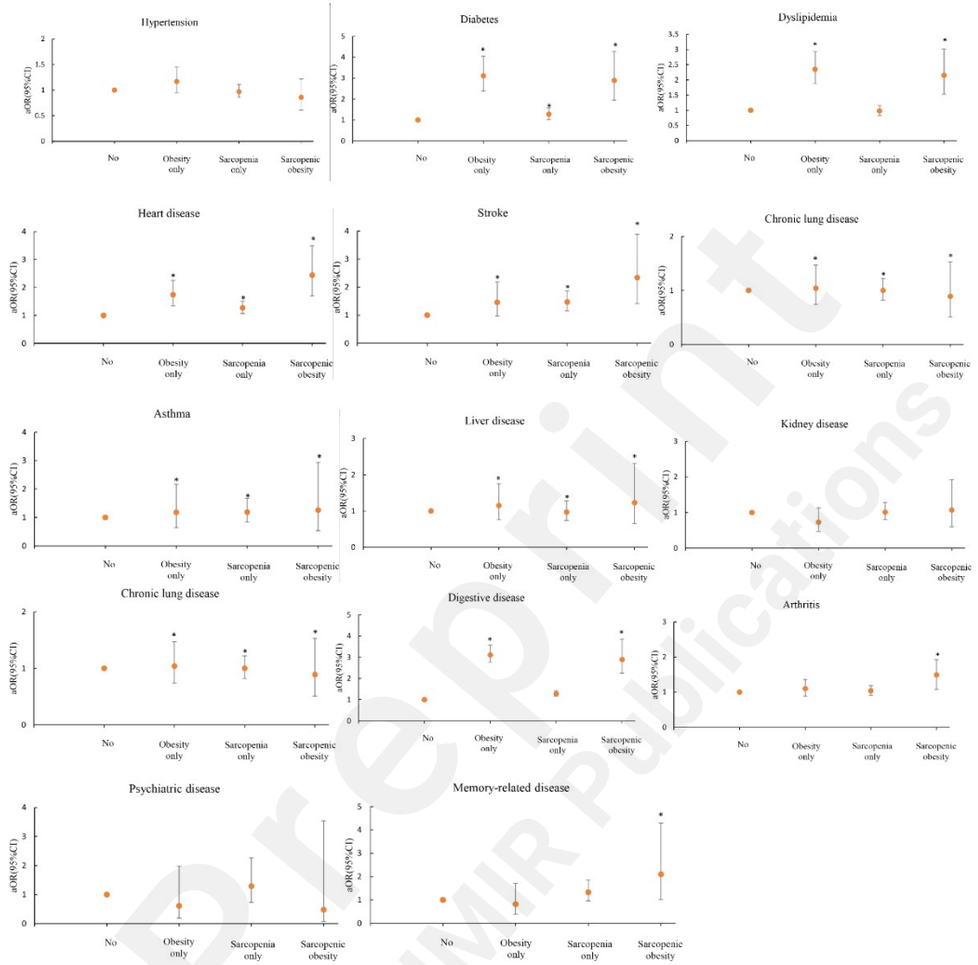

Figure 2. The adjusted odds ratio for the association between sarcopenia status, obesity with 14 chronic diseases. Model adjusted for age,

gender, BMI, educational level, marriage status, family's economic status, cigarette smoking, alcohol consumption, and residential locations. $^{*}P < 0.05$.

Supplementary Files

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