Age and gender specific association between obesity and depressive symptoms: a large-scale cross-sectional study

Wei Liao†, Zhicheng Luo†, Yitan Hou², Ningning Cui¹, Xiaotian Liu¹, Wenqian Huo¹, Fang Wang³ and Chongjian Wang¹*

Abstract

Background: This is a cross-sectional study to explore the age and gender specific association between obesity and depression in Chinese rural adults.

Methods: A total of 29,900 eligible participants from the Henan Rural Cohort Study were included. Standard anthropometric measurements were undertaken to obtain data on body mass index (BMI) and waist circumference (WC). The Patient Health Questionnaire-2 (PHQ-2) was utilized to discover depressive symptoms. Logistic regression was performed to explore the association between obesity (independent variable) and depressive symptoms (dependent variable).

Results: There were 1777 subjects with depressive symptoms, accounting for 5.94%. After multivariable adjustment, compared with normal weight group, the odds ratios (ORs) [95% confidence interval (CI)] for depressive symptoms in underweight, overweight and general obese groups were 1.41 (1.08–1.84), 0.87 (0.78–0.97) and 0.86 (0.74–0.99), respectively. Similarly, the OR (95% CI) of abdominal obesity group was 0.84 (0.76–0.93). Besides, there was linear decreasing trend of WC with depressive symptoms, but not BMI. Moreover, the inverse association between obesity and depressive symptoms was stronger in men and the elderly than that in women and the young.

Conclusion: Underweight was associated with a higher prevalence of depressive symptoms, which indicated that health care should pay attention to underweight as well as obesity, especially for women and the young.

Clinical trial registration: The Henan Rural Cohort Study has been registered at Chinese Clinical Trial Register (Registration number: ChiCTR-OOC-15006699). Date of registration: 2015-07-06.

Keywords: Depressive symptoms, Obesity, Association, age, gender

* Correspondence: tjwcj2005@126.com
† Wei Liao and Zhicheng Luo contributed equally to this work.
¹ Department of Epidemiology and Biostatistics, College of Public Health, Zhengzhou University, Zhengzhou, 100 Kexue Avenue, Zhengzhou 450001, Henan, PR China

© The Author(s). 2020 Open Access. This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.
What is already known on this topic?
Previous studies have investigated the association between obesity and depression, but the association remains controversial. Studies in Western countries have shown that obesity increases the risk of depression, while several Chinese studies have shown that obesity decreases the risk of depression. In addition, there were scarce studies conducted in Chinese rural areas and how gender and age play a role in the association remains unclear.

What does this study add?
This study found that overweight and obesity associated with a lower prevalence of depressive symptoms in the Chinese rural population. Furthermore, the findings illustrated that the inverse association between obesity and depressive symptoms was stronger in men and the elderly than that in women and the young.

How might our results change the direction of research or the focus of clinical practice?
Underweight associated with a higher prevalence of depressive symptoms, which indicated that health care should pay attention to underweight as well as obesity, especially in women and the young.

Background
Obesity is one of the most prevalent chronic condition in the world, and approximate 1.9 billion and 609 million adults worldwide were reported overweight and obese in 2015, respectively, accounting for approximately 39% of the world’s population [1]. According to the location and characteristics of fat distribution, obesity is divided into abdominal obesity and general obesity. A study from 31 provinces in mainland China showed that the prevalence of abdominal obesity in China was 29.1% from 2012 to 2015, which was a major public health challenge [2]. Over the past few years, epidemiological studies have suggested that overweight and obesity were associated with an increased risk of non-communicable diseases, such as stroke [3], cardiovascular disease, type 2 diabetes, osteoarthritis, and some cancers, contributing to a significant health burden globally [4]. In 2008, the World Health Organization listed major depression as the third leading cause of the burden of global disease, and predicted that it will rank first by 2030 [5]. According to the World Health Organization, 5% of the world’s population (more than 264 million people of all ages) suffers from depression [6].

In recent years, the association between obesity and depression have been investigated in some epidemiological studies. However, the results were controversial between western countries and China. Some studies conducted in western countries reported that obesity was associated with increased depression prevalence [7–9]. There were also some systematic review indicating that obesity increase the risks of depression [10, 11]. In addition, other studies described a U-shaped association between obesity and depression (both underweight and obesity were associated with high levels of depression) [12–14]. However, several studies conducted in China demonstrated a negative correlation between obesity and the risk of depression [15–18]. These inconsistencies may be due to different study populations, different perceptions regarding obesity, different body weight and depression criteria, and other factors.

Previous studies have widely examined the association on children, adolescents or adults [19–21]. However, scarce studies were conducted in Chinese rural adults and how gender and age play a role in the association remains unclear. Therefore, in this large population-based cross-sectional study, we aimed to explore the age and gender specific association between obesity and depression in Chinese rural adults. We hypothesize that there exists a reverse association between obesity and depressive symptoms as most Asian studies found, and this association may distinguish in different gender and age subgroups.

Methods
Study population
The study population was selected from the baseline survey of Henan Rural Cohort Study, which was conducted from July 2015 to September 2017. The Henan Rural Cohort Study was approved by the Zhengzhou University Life Science Ethics Committee and conducted in accordance with the principles of the Declaration of Helsinki (Code: [2015] MEC (S128)). Before the study commenced, participants were informed of the study’s purpose, health benefits, and potential hazards. Participants were required to provide informed consent and both the researchers and respondents agreed to use the data for scientific research purposes only.

This study used a multistage stratified cluster sampling method to recruit participants in Yuzhou, Suiping, Tongxu, Xinxiang and Yima counties of Henan province in China. Residents aged from 18 to 79 years were invited to participate in this study. We recruit participants through the local medical institutions and Centers for Disease Control and Prevention. Detailed information on the cohort has been described elsewhere [22].

A total of 39,259 were included in this study. For missing the data on depressive symptoms, 9258 participants were excluded. Due to lacking information on BMI or WC, 101 participants were excluded. Finally, 29,900 participants were included in our analysis.
Data collection and laboratory methods
A structured questionnaire was asked by well-trained research staff according to face-to-face interview. We collected participants’ information on demographic characteristics, lifestyle factors and individual history of chronic diseases. The demographic characteristics included gender, age in years (18–44, 45–54, 55–64, and 65–79), marital status (married/cohabiting, widowed/divorced/separated, and Single), educational level (Elementary school or below, Junior high school, and Senior high school or above), and average monthly income (<500 RMB, 500–RMB, and ≥1000 RMB). Lifestyle factors included smoking, alcohol drinking and physical activity. Smoking was defined as at least one cigarette per day for six sequential or cumulative months. Alcohol consumption was defined as consuming alcohol at least 12 times per year. Physical activity classified as low, moderate, high level according to International Physical Activity Questionnaire (IPAQ) [23]. Chronic diseases included hypertension, hyperlipemia, diabetes mellitus, coronary heart disease (CHD) and stroke. These chronic common diseases were collected through physical examination, laboratory tests, or self-reports.

In accordance with standardized protocols [24], body height and weight of the participants were measured twice with shoes and coats off and the readings were recorded to the nearest 0.1 cm and 0.1 kg, respectively. WC was also measured twice with a standard tape around the waist about 1 cm above the navel and parallel to the ground. The average readings of the two measures were taken for statistical analysis. BMI was calculated as weight (kilogram) divided by height (meter) squared based on the measurement.

Definition of obesity
In accordance with the Chinese standard of BMI and WC [25]: BMI < 18.5 kg/m², 18.5 ≤ BMI < 24.0 kg/m², 24.0 ≤ BMI < 28.0 kg/m² and BMI ≥ 28.0 kg/m² were for underweight, normal weight, overweight and general obesity, respectively; WC < 90 cm for men and WC < 80 cm for women were classified as normal waist circumference, and WC ≥ 90 cm for men and WC ≥ 80 cm for women were classified as abdominal obesity. In accordance with the World Health Organization standard of BMI and WC [26]: BMI < 18.5 kg/m², 18.5 ≤ BMI < 24.9 kg/m², 25.0 ≤ BMI < 29.9 kg/m² and BMI ≥ 30.0 kg/m² were for underweight, normal weight, overweight and general obesity, respectively; WC < 102 cm for men and WC < 88 cm for women were classified as normal waist circumference, and WC ≥ 102 cm for men and WC ≥ 88 cm for women were classified as abdominal obesity.

Assessment of depressive symptoms
The Patient Health Questionnaire-2 (PHQ-2) is an abbreviated version of the Patient Health Questionnaire-9 (PHQ-9), which has been widely used for screening depressive symptoms in epidemiological survey. The screening accuracy of the PHQ-2 was satisfactory, with a Patient Health Questionnaire-2 item cutoff of ≥3 [27]. It is consisted of two core items: “little interest or pleasure in doing things” and “feeling down, depressed, or hopeless”. Each item consists of four levels (0 - never; 1 - several days; 2 - more than half the time; and 3 - nearly every day). Thus, the total scores of PHQ-2 is between 0 and 6. In this study, we utilized PHQ-2 scale to identify participants’ depressive symptoms with a cutoff of 3.

Statistical analysis
Continuous variables were described by mean with standard deviation (SD), while categorical variables were described by frequency with percentages. T test or chi-square test was utilized to compare differences between depressive symptoms group and non-depressive symptoms group.

The association between obesity (independent variable) and depressive symptoms (dependent variable) was examined by binary logistic regression analyses. Model 1 was unadjusted. Model 2 was further adjusted for age and gender. Model 3 was adjusted for age, gender, educational level, marital status, average monthly individual income, current smoking, current alcohol drinking, physical activity, and individual history of chronic diseases (including coronary heart disease, stroke, hypertension, diabetes and dyslipidemia). To identify the dose-response association between BMI and WC and depressive symptoms, restricted cubic spline [28] model was applied where 21 kg/m² of BMI and 80 cm of WC were as the reference group. Finally, a visual interaction effect was illustrated in order to explore how the effects of BMI and WC on depressive symptoms altered with age.

The figures were produced using the R language software 3.5.2. Statistical analyses were performed by SPSS 21.0 software package (SPSS Institute, Chicago), and all P values were two-tailed with a statistical significance level of 0.05.

Results
Table 1 presents the demographic and socioeconomic characteristics of the study population stratified by depressive symptoms. The mean age of the 29,900 participants was 55.43 (SD: 12.356) years, and 59.21% were women. In this study, a total of 1777 subjects were identified as having depressive symptoms with a prevalence of 5.94%. Compared with non-depressive group, depressive group were older, had lower educational level and average monthly income, more likely to be women and have chronic disease history (all P < 0.05). Individuals with depressive symptoms were less likely to be current smokers, current drinkers and married than those
without depressive symptoms (all $P < 0.05$). Besides, individuals with depressive symptoms were more prone to have a lower level of BMI (24.43 vs. 24.75) and WC (82.41 vs. 83.78). Supplementary Table 1 shows the distributions of selected variables of the participants stratified by obesity status. There are significant differences statistically in all demographic and socioeconomic characteristics (all $P < 0.05$).

Odds ratios for depressive symptoms associated with BMI and WC are presented in Table 2. BMI and WC were considered as both categorical variables according to Chinese criteria and continuous variable scaled to 1-kg/m$^2$ and 1-cm increase, respectively. After multivariable adjustment, compared with normal weight group, the odds ratios for depressive symptoms in underweight, overweight and general obese groups were 1.41 (1.08–1.84), 0.87 (0.78–0.97) and 0.86 (0.74–0.99), respectively. Moreover, the OR of depressive symptoms associated with 1 kg/m$^2$ increase in BMI was 0.97 (0.95–0.98). Similarly, abdominal obesity was associated with a lower prevalence of depressive symptoms. Supplementary Table 2 presents the association between obesity and depressive symptoms according to BMI and WC in WHO definition. The results were consistent with the results using Chinese standards. The dose-response relationships of BMI and WC with depressive symptoms are further evaluated through the restricted cubic spline curves in Fig. 1, which suggested that the prevalence of depressive symptoms may be lower with a higher level of WC ($P$ for non-linear trend = 0.108), but not BMI ($P$ for non-linear trend = 0.017).

Table 3 demonstrates the association between BMI and WC and depressive symptoms according to gender. Among men, the risks of depressive symptoms in underweight, overweight and general obese groups were 1.62 (1.08–2.43), 0.83 (0.69–0.99) and 0.68 (0.52–0.90) compared with normal weight group in the crude model. After multivariable adjustment, the ORs in underweight and overweight groups became borderline non-significant. However, there were no significant associations between BMI groups and depressive symptoms among women. According to the WC category, compared with those who had normal waist circumference, participants with abdominal obesity associated with a

**Table 1** Distributions of selected variables of the participants stratified by depressive symptoms status

| Variables                              | Overall (n = 29,900) | Non-DS (n = 28,123) | DS (n = 1777) | P value $^*$ |
|----------------------------------------|----------------------|---------------------|--------------|-------------|
| Age (year, mean ± SD)                  | 55.43 ± 12.356       | 55.38 ± 12.383      | 56.23 ± 11.894 | 0.005       |
| Women (n, %)                           | 17,704 (59.21)       | 16,504 (58.69)      | 1200 (67.53)  | < 0.001     |
| Educational level (n, %)               |                      |                     |              |             |
| Elementary school or below             | 13,324 (44.23)       | 12,279 (43.66)      | 945 (53.18)  | < 0.001     |
| Junior high school                     | 11,647 (38.95)       | 11,022 (39.19)      | 625 (35.17)  |             |
| Senior high school or above            | 5029 (16.82)         | 4822 (17.15)        | 207 (11.65)  |             |
| Marital status (n, %)                  |                      |                     |              |             |
| Married/cohabiting                     | 26,968 (90.19)       | 25,407 (90.34)      | 1561 (87.84) | 0.002       |
| Widowed/separated/divorced             | 2423 (8.10)          | 2242 (7.97)         | 181 (10.19)  |             |
| Single                                 | 509 (1.71)           | 474 (1.69)          | 35 (1.97)    |             |
| Average monthly income (n, %)          |                      |                     |              |             |
| < 500 RMB                              | 10,795 (36.10)       | 9954 (35.39)        | 841 (47.32)  | < 0.001     |
| 500–RMB                                | 9416 (31.49)         | 8948 (31.82)        | 468 (26.34)  |             |
| ≥ 1000 RMB                             | 9689 (32.41)         | 9221 (32.79)        | 468 (26.34)  |             |
| Physical activity (n, %)               |                      |                     |              |             |
| Low                                    | 9501 (31.78)         | 8905 (31.66)        | 596 (33.54)  | 0.177       |
| Moderate                               | 11,009 (36.82)       | 10,357 (36.83)      | 652 (36.69)  |             |
| High                                   | 9390 (31.40)         | 8861 (31.51)        | 529 (29.77)  |             |
| Current smokers (n, %)                 | 6005 (20.08)         | 5725 (20.36)        | 280 (15.76)  | < 0.001     |
| Current drinkers (n, %)                | 5219 (17.45)         | 5008 (17.81)        | 211 (11.87)  | < 0.001     |
| Chronic disease (n, %)                 | 17,755 (59.38)       | 16,654 (59.50)      | 1101 (62.06) | 0.033       |
| Body mass index (kg/m$^2$, mean ± SD)  | 24.73 ± 3.569        | 24.75 (3.559)       | 24.43 (3.708) | < 0.001     |
| Waist circumference (cm, mean ± SD)    | 83.70 ± 10.469       | 83.78 (10.450)      | 82.41 (10.699) | < 0.001     |

Abbreviation: DS depressive symptoms; SD standard deviation; RMB Renminbi

$^*$ T-test was performed to compare the differences in continuous variables; Chi-square test was used to compare the differences in the categorical variables.
lower prevalence of depressive symptoms among men and women. Notably, the inverse association between abdominal obesity and depressive symptoms was stronger in men than that in women ($P < 0.05$).

Age specific association between obesity and depressive symptoms is shown in Table 4. Among participants aged from 18 to 44 year, the risks of depressive symptoms in underweight, overweight and general obese groups were all higher than that in normal weight group, although these associations were not statistically significant. In the other two age groups, underweight participants had higher ORs for depressive symptoms while participants with overweight and general obesity had lower ORs compared with normal weight people. According to the WC category, participants with abdominal obesity associated with a lower prevalence of depressive symptoms than those with normal waist circumference among people aged 45 years or above. Gender and age specific association between obesity and depressive symptoms according to WHO criteria are

### Table 2 Association between obesity and depressive symptoms according to BMI and WC

| Variables  | No. of cases | Model 1 OR (95% CI) | Model 2 OR (95% CI) | Model 3 OR (95% CI) |
|------------|--------------|---------------------|---------------------|---------------------|
| **BMI (kg/m²)** |              |                     |                     |                     |
| Continuous | 29,900       | 0.97 (0.96–0.99)    | 0.97 (0.96–0.99)    | 0.97 (0.95–0.98)    |
| Category   |              |                     |                     |                     |
| Underweight (< 18.5) | 779          | 1.44 (1.11–1.87)    | 1.43 (1.11–1.86)    | 1.41 (1.08–1.84)    |
| Normal weight (18.5–23.9) | 12,365      | Reference           | Reference           | Reference           |
| Overweight (24.0–27.9) | 11,668       | 0.89 (0.80–0.99)    | 0.89 (0.80–0.99)    | 0.87 (0.78–0.97)    |
| General obesity (≥28.0) | 5088         | 0.90 (0.78–1.04)    | 0.88 (0.77–1.02)    | 0.86 (0.74–0.99)    |
| **WC (cm)** |              |                     |                     |                     |
| Continuous | 29,900       | 0.99 (0.98–0.99)    | 0.99 (0.98–0.99)    | 0.99 (0.98–0.99)    |
| Category   |              |                     |                     |                     |
| Normal WC  | 15,143       | Reference           | Reference           | Reference           |
| Abdominal obesity | 14,757       | 0.95 (0.86–1.04)    | 0.85 (0.77–0.93)    | 0.84 (0.76–0.93)    |

*Abbreviation: BMI body mass index; WC waist circumference*

Model 1: unadjusted;
Model 2: adjusted for age and gender;
Model 3: adjusted for age, gender, educational level, marital status, average monthly income, physical activity, current smoking, current drinking and chronic disease (including coronary heart disease, stroke, hypertension, diabetes and dyslipidemia)

*a Abdominal obesity was classified as WC ≥ 80 cm for women and WC ≥ 90 cm for men*

**Fig. 1** The dose-response relationships of BMI and WC with depressive symptoms
The results were consistent with the results using Chinese standards. In addition, interactive association of BMI/WC and age on depressive symptoms is illustrated in Fig. 2. As shown, the negative associations of BMI/WC with depressive symptoms were enhanced by increasing age (both \( P < 0.05 \)). The interactive association of BMI/WC and age on depressive symptoms in men and women are shown in Supplementary Fig. 1 and 2, respectively. The results demonstrated that the negative associations of BMI/WC with depressive symptoms were enhanced by increasing age in both men and women.

**Discussion**

To the best of our knowledge, this research is the first study to explore the association of obesity with depression in Chinese rural population. The inverse association between obesity and depression were found in this study. Besides, there was linear trend for the dose-response relationships of WC with depressive symptoms, but not BMI. In addition, the inverse association between abdominal obesity and depressive symptoms was stronger in men than that in women. The inverse association between BMI/WC and depressive symptoms increased as age increased.

Our finding of the inverse association between obesity and depression among Chinese rural population was consistent with those reported in Korea, Taiwan and Japan [19, 29–31]. In addition, some previous studies in China have also observed an inverse association between obesity and depression [15, 16]. Conversely, some studies conducted in western countries reported that obesity was associated with increased depression prevalence [32–34]. These inconsistencies may be due to different study populations, different perceptions regarding obesity, different body weight and depression criteria, and other factors.

The negative relationship between obesity and depression can be explained by the “jolly fat” hypothesis which was first reported by Crisp and his colleagues [35]. Crisp

---

**Table 3** Gender-specific association between obesity and depressive symptoms

| Variables       | No. of cases | Model 1 OR (95% CI) | Model 2 OR (95% CI) | Model 3 OR (95% CI) |
|-----------------|--------------|---------------------|---------------------|---------------------|
| BMI (kg/m²)     |              |                     |                     |                     |
| **Men**         |              |                     |                     |                     |
| Underweight     | 342          | 1.62 (1.08–2.43)    | 1.64 (1.09–2.45)    | 1.47 (0.98–2.23)    |
| Normal weight   | 5339         | Reference           | Reference           | Reference           |
| Overweight      | 4640         | 0.83 (0.69–0.99)    | 0.82 (0.68–0.99)    | 0.85 (0.70–1.02)    |
| General obesity | 1875         | 0.68 (0.52–0.90)    | 0.67 (0.51–0.88)    | 0.67 (0.51–0.90)    |
| \( P \) for trend | < 0.001     | < 0.001             | < 0.001             | 0.001               |
| **Women**       |              |                     |                     |                     |
| Underweight     | 437          | 1.34 (0.96–1.88)    | 1.33 (0.95–1.86)    | 1.36 (0.97–1.92)    |
| Normal weight   | 7026         | Reference           | Reference           | Reference           |
| Overweight      | 7028         | 0.92 (0.80–1.04)    | 0.90 (0.79–1.03)    | 0.88 (0.77–1.01)    |
| General obesity | 3213         | 0.98 (0.83–1.15)    | 0.96 (0.81–1.13)    | 0.91 (0.77–1.08)    |
| \( P \) for trend | 0.194      | 0.127               | 0.045               |                     |
| WC (cm)\(^a\)   |              |                     |                     |                     |
| **Men**         |              |                     |                     |                     |
| Normal WC       | 8037         | Reference           | Reference           | Reference           |
| Abdominal obesity | 4159      | 0.73 (0.61–0.88)    | 0.73 (0.60–0.87)    | 0.76 (0.62–0.92)    |
| **Women**       |              |                     |                     |                     |
| Normal WC       | 7106         | Reference           | Reference           | Reference           |
| Abdominal obesity | 10,598    | 0.92 (0.82–1.03)    | 0.88 (0.78–0.99)    | 0.85 (0.76–0.97)    |
| \( P \) for interaction | 0.043  | 0.068               | 0.426               |                     |

*Abbreviation: BMI body mass index; WC waist circumference*

Model 1: unadjusted;
Model 2: adjusted for age and gender;
Model 3: adjusted for age, gender, educational level, marital status, average monthly income, physical activity, current smoking, current drinking and chronic disease (including coronary heart disease, stroke, hypertension, diabetes and dyslipidemia).

\(^a\) Abdominal obesity was classified as WC \( \geq 80 \) cm for women and WC \( \geq 90 \) cm for men.
proposed that there was a significant positive relationship between substantial obesity and low levels of depression in men. The special phenomenon has also been found in several other studies [36–38]. This hypothesis could be explained by losing weight through diet restriction which may be an important factor in inducing depression. Thus, people who lost weight through dieting have high risk of depression [35].

In this study, the participants are Chinese rural population; therefore, Chinese traditional culture may be another factor influencing the inverse relationship between obesity and depression. In Chinese traditional culture, having a good appetite is a blessing and being obesity represents good social and economic status [39]. It is different from western countries that excessive body weight was usually stigmatized [40].

**Table 4** Age-specific association between obesity and depressive symptoms

| Variables                  | No. of cases | Model 1 OR (95% CI) | Model 2 OR (95% CI) | Model 3 OR (95% CI) |
|----------------------------|--------------|---------------------|---------------------|---------------------|
| **BMI (kg/m²)**            |              |                     |                     |                     |
| 18–44 years old            |              |                     |                     |                     |
| Underweight                | 53           | 1.48 (0.80–2.74)    | 1.48 (0.80–2.74)    | 1.47 (0.78–2.74)    |
| Normal weight              | 733          | Reference           | Reference           | Reference           |
| Overweight                 | 773          | 1.09 (0.83–1.44)    | 1.09 (0.83–1.44)    | 1.10 (0.83–1.46)    |
| General obesity            | 446          | 1.23 (0.88–1.71)    | 1.23 (0.88–1.71)    | 1.24 (0.87–1.76)    |
| P for trend                | 0.465        | 0.481               | 0.468               |                     |
| 45–59 years old            |              |                     |                     |                     |
| Underweight                | 49           | 1.81 (1.06–3.09)    | 1.77 (1.03–3.01)    | 1.76 (1.03–3.03)    |
| Normal weight              | 1733         | Reference           | Reference           | Reference           |
| Overweight                 | 1837         | 0.88 (0.74–1.05)    | 0.87 (0.73–1.03)    | 0.85 (0.72–1.02)    |
| General obesity            | 810          | 0.86 (0.69–1.07)    | 0.85 (0.68–1.06)    | 0.81 (0.64–1.01)    |
| P for trend                | 0.032        | 0.022               | 0.010               |                     |
| 60–79 years old            |              |                     |                     |                     |
| Underweight                | 240          | 1.32 (0.94–1.86)    | 1.33 (0.94–1.87)    | 1.26 (0.89–1.79)    |
| Normal weight              | 2873         | Reference           | Reference           | Reference           |
| Overweight                 | 2030         | 0.84 (0.71–0.98)    | 0.80 (0.68–0.94)    | 0.81 (0.68–0.95)    |
| General obesity            | 619          | 0.83 (0.67–1.04)    | 0.76 (0.61–0.94)    | 0.75 (0.60–0.94)    |
| P for trend                | 0.004        | < 0.001             | 0.001               |                     |
| **P for interaction**      | 0.047        | 0.006               | 0.021               |                     |
| **WC (cm)**                |              |                     |                     |                     |
| 18–44 years old            |              |                     |                     |                     |
| Normal WC                  | 1218         | Reference           | Reference           | Reference           |
| Abdominal obesity          | 787          | 0.94 (0.74–1.21)    | 0.94 (0.74–1.21)    | 0.96 (0.74–1.25)    |
| 45–59 years old            |              |                     |                     |                     |
| Normal WC                  | 2685         | Reference           | Reference           | Reference           |
| Abdominal obesity          | 1744         | 0.96 (0.82–1.11)    | 0.86 (0.73–1.01)    | 0.84 (0.71–0.99)    |
| 60–79 years old            |              |                     |                     |                     |
| Normal WC                  | 4134         | Reference           | Reference           | Reference           |
| Abdominal obesity          | 1628         | 0.93 (0.81–1.08)    | 0.76 (0.65–0.89)    | 0.77 (0.65–0.90)    |
| **P for interaction**      | 0.238        | 0.035               | 0.087               |                     |

Abbreviation: BMI body mass index; WC waist circumference
Model 1: unadjusted;
Model 2: adjusted for age and gender;
Model 3: adjusted for age, gender, educational level, marital status, average monthly income, physical activity, current smoking, current drinking and chronic disease (including coronary heart disease, stroke, hypertension, diabetes and dyslipidemia)

* Abdominal obesity was classified as WC ≥ 80 cm for women and WC ≥ 90 cm for men
The inverse relationship may also be the result of biological molecular mechanism. Neuropeptide Y (NPY) is a 36-amino acid peptide that widely distributed in the central nervous system and it may explain the association between increased body mass and reduced depressive symptoms [41]. According to the result of forced swimming test on mice which was widely used to screen for potential antidepressants [42], NPY treatment could increase the number of swimming times of animals and reduce the immobilization of the forced swimming test, indicating that NPY had antidepressant effect and could increase appetite [43].

The current study indicated that the inverse association between abdominal obesity and depressive symptoms was stronger in men than that in women. It may be due to women had more hormonal fluctuations and excessive sensitivity to hormonal fluctuations than men [44]. Besides, there were also a lot of other factors accounting for the increased probability of depression among women such as psychosocial events, victimization, sex-specific socialization, internalization coping style, and disadvantaged social status [45].

Furthermore, the inverse association of BMI and WC with depressive symptoms became stronger as age increased. It may result from the difference on the self-perception of being fat between the young and old. Having a self-perception of being fat produced a potentiating effect, significantly increasing the likelihood of...
depression [46]. In addition, nowadays, images of unrealistically thin and stigmatization of obesity are disseminated in the current society [47, 48]. Therefore, the internalization of the media ideal of thinness affects more and more modern people, especially the young ones.

The large sample size is an advantage of this study. There were some limitations in our study. First, we could not identify the causal relationships between obesity and depression because the study was conducted at the cross-sectional level. Thus, more prospective studies need to be done. Second, depressive symptoms in our study were assessed by the Patient Health Questionnaire-2 (PHQ-2) based on self-report of participants, which might cause recall bias. Although our scale is short, it is effective and very applicable in the large epidemiologic field investigation. In addition, as an important factor for both obesity and depressive symptoms, diet was not included in the analysis which may affect our results.

Conclusions
The results of this study suggested that obesity was associated with a lower prevalence of depressive symptoms, which supported the “jolly fat” hypothesis in China. The findings indicated that health care should pay attention to underweight as well as obesity. In addition, gender and age specific differences between obesity measures and depressive symptoms were found. Thus, targeted strategies on preventing depression are needed to pay more attention to women and the young. In the future, prospective studies are wanted to better explore the mechanism of this association.

Supplementary information
Supplementary information accompanies this paper at https://doi.org/10.1186/s12889-020-09664-8.

Additional file 1.

Abbreviations
BMI: Body mass index; CI: Confidence interval; CHD: Coronary heart disease; DS: Depressive symptoms; IPAQ: International Physical Activity Questionnaire; NPY: Neuropeptide Y; ORs: Odds ratios; PHQ-2: Patient Health Questionnaire-2; PHQ-9: Patient Health Questionnaire-9; RNB: Renminbi; SD: Standard deviation; WC: Waist circumference; WHO: World Health Organization

Acknowledgments
The authors thank all of the participants, coordinators, and administrators for their support and help during the research. In addition, the authors would like to thank Dr. Tanko Abdulai for his critical reading of the manuscript.

Authors’ contributions
CW and FW conceived and designed the study. ZL, YH, NC, XL and WH collected data. WL, ZL, YH and NC analyzed the data and took responsibility for the integrity and accuracy of the information. WL, ZL, XL and WH drafted the manuscript. All authors critically reviewed the manuscript. All authors have read and approved the final manuscript.

Funding
This research was supported by the Foundation of National Key Program of Research and Development of China (Grant NO: 2016YFC0900803); National Natural Science Foundation of China (Grant NO: U1404814, 81573243, 81602925); Foundation of Key Scientific and Technological Project of Henan Province (Grant NO:182102310062); Science and Technology Foundation for Innovation Talent of Henan Province (Grant NO: 164100510021); Science and Technology Innovation Talents Support Plan of Henan Province Colleges and Universities (Grant NO: 14HASTIT035); High-level Personnel Special Support Project of Zhengzhou University (Grant NO: ZDGJD13001). The funders did not influence any stage of this study.

Availability of data and materials
The data analyzed during current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
Ethics approval was obtained from the “Zhengzhou University Life Science Ethics Committee”, and written informed consent was obtained for all participants. Ethics approval code: [2015] MEC (S128).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
1Department of Epidemiology and Biostatistics, College of Public Health, Zhengzhou University, Zhengzhou, 100 Xueyue Avenue, Zhengzhou 450001, Henan, PR China. 2Department of Global Health, School of Health Sciences, Wuhan University, Wuhan, Hubei, China. 3Department of Epidemiology, School of Public Health, Shaxi Medical University, Talyuan, Shaxi, PR China.

Received: 28 April 2020 Accepted: 8 October 2020
Published online: 17 October 2020

References
1. Chooi YC, Ding C, Magkos F. The epidemiology of obesity. Metabolism. 2019;92:6–10. https://doi.org/10.1016/j.metabol.2018.09.005.
2. Zhang L, Wang Z, Wang X, et al. Prevalence of abdominal obesity in China: results from a cross-sectional study of nearly half a million participants. Obesity (Silver Spring). 2019;27(11):1898–905. https://doi.org/10.1002/oby.22260.
3. Shakiba M, Mansournia MA, Kaufman JS. Estimating effect of obesity on stroke using G-estimation: the ARIC study. Obesity (Silver Spring). 2019;27(2): 504–8. https://doi.org/10.1002/oby.22365.
4. GBD. Obesity collaborators, Afshin a, Forouzanfar MH, et al. health effects of overweight and obesity in 195 countries over 25 years. N Engl J Med. 2015;377(1):13–27. https://doi.org/10.1056/nejma1614362.
5. World Health Organization. The global burden of disease. Geneva: World Health Organization; 2008. p. 42–9.
6. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/depression. Updated January 30, 2020. Accessed 28 Feb 2020.
7. Tyrrell J, Mulguta A, Wood AR, et al. Using genetics to understand the causal influence of higher BMI on depression. Int J Epidemiol. 2019;48(3): 834–48. https://doi.org/10.1093/ije/dyy223.
8. Koksal U, Ertuzk Z, Koksal AR, Ozsenel EB, Kaptanogullari OH. What is the importance of body composition in obesity-related depression? Eurasian J Med. 2017;49(2):102–6. https://doi.org/10.5152/eurasijmed.2017.16129.
9. Dolevian A, Araghi SM, Qorbani M, Pishva H. The relationship between body mass index (BMI) and depression according to the rs16139NPY gene. Iran J Psychiatry. 2017;12(3):201–5.
10. Atlantis E, Baker M. Obesity effects on depression: systematic review of epidemiological studies. Int J Obes. 2008;32(6):881–91. https://doi.org/10.1038/sj.ijo.2008.54.
11. Luppino FS, de Wit LM, Bovuy PF, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. Arch Gen Psychiatry. 2010;67(3):220–9. https://doi.org/10.1001/archgenpsychiatry.2010.2.
