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Association between the BMI and depression symptoms in the U.S. older adults base on NHANES

Kexin Li

The London school of Economics And Political Science, London, UK, WC2A 2HD

likexin2021@outlook.com

Abstract. Depression ranks among the most prevalent mental health conditions globally, with major depression being more common in elder people. Nonetheless, the link between depressive symptoms and body mass index (BMI) remains ambiguous. The purpose of this study was to investigate the correlation between BMI and symptoms of depression in American elders. In this paper, a cross-sectional study was conducted involving 7,769 participants aged 60 years or older, with all data collected from the 2005-2016 National Health Survey (NHANES). We employed a multivariate logistic regression analysis to evaluate the association between levels of BMI (as independent variables) and presence of symptoms of depression (as outcome variables). Depressive symptoms were primarily assessed using the Patient Health Questionnaire (PHQ-9). Additionally, in this paper, several sensitivity analyses are performed to verify the robustness of our findings. After adjusting for covariates, the final model shows the ORS(95%CI) of underweight and obese people are 1.52(0.78,2.98) and 1.34(0.94,1.93), respectively. And there is a non-linear and U-shaped relationship between the BMI and the depressive symptoms. Both underweight and obese people have a higher incidence of depression in elder people. To validate the association between depression and weight and their causal link, more research is required.

Keywords: Depression, Body Mass Index(BMI), Elder People, NHANES

1. Introduction

In more than 5% of people worldwide, depression is a common mental illness, according to the World Health Organization (WHO) [1]. Depression that strikes people 60 years of age or older is known as “late-life depression”. And it has been largely under-diagnosed and under-treated [2]. But it can have severe health outcomes, which include a greater risk of death, suicide, physical disability, and poor quality of life [3]. More than half of cases represent a first onset in later life [4]. From a public health perspective, since elderly depression tends to be chronic and/or recurrent, Insufficient identification and management of depression in elderly individuals lead to higher usage of health care services and impose a strain on both patients and their families.

Approximately one-third of the US population is obese, while another one-third is overweight [5]. Previous systematic reviews and meta-analyses have highlighted a bidirectional link between obesity and depression. It was shown that persons who were obesity exhibited a 55% elevated probability of encountering depression, whereas those who were depressed had a 58% heightened potential of developing obesity [6]. A potential explanation for this phenomenon could be attributed to several

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prevalent risk factors associated with obesity and depression, including but not limited to low socioeconomic level, inadequate sleep, and the consumption of tobacco and alcohol, which may contribute to the prevalence of both diseases [7].

While there is a well-established connection with obesity, the association between Body Mass Index (BMI) and depression does not display consistent patterns. Research presents varied findings: certain studies suggest a direct positive correlation with higher BMI elevating depression risk, yet this link appears confined to individuals with a BMI in the range of severe obesity (35-39.9 or higher) in other studies [8]. Moreover, a subset of the research suggests a non-linear, U-shaped correlation between BMI and sign of depression, particularly noted in adults over the age of 50 up to centenarians [9].

The primary objective of this study was to investigate the possible association between body mass index (BMI) and depression among individuals aged 60 years and above in the United States, while considering the potential influence of different confounding factors, in light of the diverse results reported in other studies.

2. Methods

2.1. Survey Description

The National Center for Health Statistics, a division of the Centers for Disease Control and Prevention, is responsible for administering the National Health and Nutrition Examination Survey (NHANES), a population-based, cross-sectional survey aimed at estimating the health and nutritional status of the American people. The poll used a sophisticated multi-stage stratified methodology that oversampled older individuals and members of underrepresented groups. Highly skilled personnel conducted the examinations and interviews, and automated data gathering methods were applied. The respondent and, if required, the respondent's proxy were the targets of questions. To ensure a sufficient sample size for our analysis, we utilized data from the National Health and Nutrition Examination Survey (NHANES) collected during the cycles of 2007–2008, 2009–2010, 2011–2012, 2013–2014, and 2015–2016. The NHANES study protocol received approval from the Research Ethics Review Board of the National Center for Health Statistics, with all participants providing signed informed consent. For more comprehensive information on the NHANES, including questionnaires, datasets, and related documentation, please visit the NHANES website at the Centers for Disease Control and Prevention (cdc.gov) [10].

2.2. Study population

From 5 cycles, of the 50,588 participants interviewed by NHANES between 2007 and 2016, 9,760 participants over the age of 18 qualified as a subsample for this study. And after excluding individuals with an unfilled depression score and other covariates, the final number of participants is 7831. See the flowchart below figure 1.

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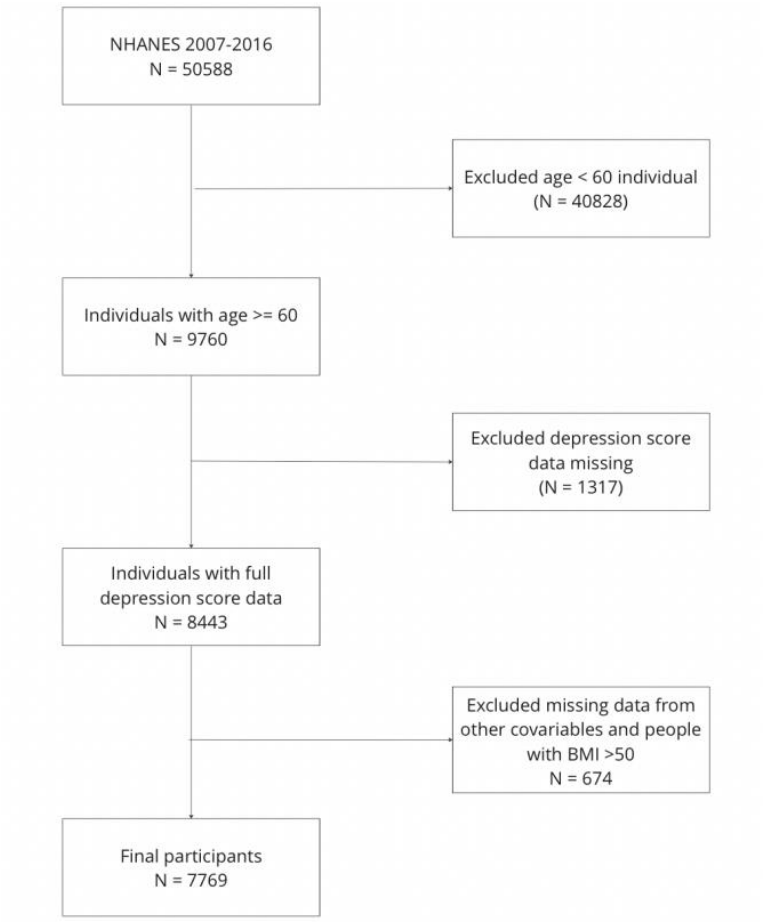

Figure 1. Flowchart of participants inclusion (National Health and Nutrition Examination Survey [NHANES])

2.3. Measurement

2.3.1. Outcome variables. The Patient Health Questionnaire (PHQ-9), which is used to assess depression within the past two weeks, is a brief but effective tool for assessing depressive symptoms. The questionnaire consists of nine items that reflect the signs and symptoms listed in the Diagnostic and Statistical Manual of Mental Disorders, with each item scored on a scale from 0 to 3 (0 = none, 1 = a few days, 2 = more than half the time, and 3 = almost every day), with a total score ranging from 0 to 27. According to previous studies, a PHQ-9 score of 10 or more usually indicates depression. The sensitivity and specificity for diagnosing major depression is 88% [12]. In the present study, depressive symptoms were coded as 0 (no depression, 0-9 points) or 1 (depression, 10-27 points) based on this threshold.

2.3.2. Exposure measurement. By dividing weight in kilograms by height in meters squared and rounding to the nearest decimal point, one can compute body mass index (BMI). The WHO recommendations [13] served as the basis for the cut-off criteria that were employed. Subjects were classified as underweight if their body mass index (BMI) was less than 18.50 kg/ m^2, normal if it was between 18.50 and 24.99 kg/m^2, overweight if it was between 25 and 29.99 kg/ m^2, and obese if it was greater than 30 kg/m^2.

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2.3.3. Covariate assessment. The prior literature served as the basis for the covariate selection. Data on age, gender, race/ethnicity, education, marital status, annual family income, recent tobacco use, recent alcohol issues, length of sleep, hypertension, and diabetes were gathered using standardized questionnaires. An ongoing variable was age, expressed in years. Either male or female was listed as the gender. There were four categories for race/ethnicity: non-Hispanic black, non-Hispanic white, and other. Education was classified into three levels: not completing high school, completing high school or an equivalent, and completing higher education. The two categories of marital status were single and cohabiting. The three categories of annual household income were <$25,000, $25,000–$75,000, and ≥$75,000.

Recent smoking status was established by responses to: "Do you now smoke cigarettes?" and "Have you smoked at least 100 cigarettes in life?" Respondents who indicated "some days" or "every day" to the first question and "yes" to the subsequent question were categorized as active smokers. Regarding recent drinking problems, participants were requested to ask "On how many days in the past 12 months have you had 4 (female)/5 (male) drinks or more of alcoholic beverages? Participants who answered ≥1 were judged to have had a recent drinking problem.

Weekday or weekday sleep duration was self-reported by participants. For the 2007-2014 cycle, sleep duration was calculated from a question posed to NHANES participants about the participant's daily sleep duration: "How much sleep do you get (in hours)?" In the 2015-2016 cycle, sleep duration was determined based on the response to the query, "How much sleep do you typically get on weekdays or nights during the week?" The categories for sleep duration were less than 7 hours, 7 to 9 hours, and 9 hours or more. The presence of diabetes and hypertension was ascertained by inquiring with participants whether a doctor or healthcare professional had ever diagnosed them with diabetes or hypertension.

2.4. Statistical analysis

Weights, clusters, and strata were adjusted using the survey settings. Frequencies and percentages were computed for categorical variables; all estimates and 95% confidence intervals (95%CI) were weighted to ensure that they were nationally representative. The analysis incorporated the Mobile Examination Center (MEC) sample weights and the relevant house investigated sample design factors (strata, primary sampling unit) to accommodate the intricate survey design. Table 1 illustrates the major demographic and clinical characteristics of the participants involved in the study.

Table 1. Baseline Characteristics of Cohort

Variable	Depression	Normal	P-value
Age, in years	68.36(0.36)	69.68(0.14)	< 0.001
Gender:			< 0.0001
Female	374(7.57)	3559(92.43)	
Male	229(4.73)	3607(95.27)	
Race/Ethnicity:			< 0.0001
Hispanic	218(12.62)	1514(87.38)	
Non-Hispanic Black	112(7.41)	1471(92.59)	
Non-Hispanic White	244(5.58)	3669(94.42)	
Other	29(6.40)	512(93.60)	
Education:			< 0.0001
≤High school	287(11.59)	2042(88.41)	
>High school	193(4.47)	3433(95.53)	
High school	123(6.53)	1691(93.47)	
Marital Status:			< 0.0001

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Table 1. (continued)

Living alone	343(9.08)	2897(90.92)	
Living together	260(4.72)	4269(95.28)	
AHI(Annual Household Income)			< 0.0001
<25000	347(12.10)	2457(87.90)	
>75000	33(2.03)	1435(97.97)	
25000-75000	223(5.67)	3274(94.33)	
Recent Smoking:			0.002
non-smoker	249(5.00)	3540(95.00)	
Recent Smoking	354(7.50)	3626(92.50)	
BMI Category:			< 0.0001
Underweight	11(8.34)	91(91.66)	
Normal	113(4.86)	1730(95.14)	
Overweight	179(4.88)	2651(95.12)	
Obese	300(8.45)	2694(91.55)	
Hypertension:			0.002
Hypertension	422(7.23)	4373(92.77)	
Normal	181(4.93)	2793(95.07)	
Diabetes:			< 0.0001
Diabetes	222(10.34)	1618(89.66)	
Normal/Borderline	381(5.29)	5548(94.71)	
sleep:			0.01
<7h	384(7.13)	3927(92.87)	
7h-9h	169(4.93)	2825(95.07)	
>9h	50(8.59)	414(91.41)	
Drinking Problem Recently			< 0.0001
Have drinking problem recently	66(4.82)	747(95.18)	
Normal	192(4.70)	3166(95.30)	
Unknown	345(8.75)	3253(91.25)	

Note. Means ± standard errors (SE) are presented for continuous variables, counts (weighted percentages) for categorical variables.

The investigation used logistic regression analysis to examine the link between depression symptoms and Body Mass Index (BMI) through three separate models related to BMI figures. The first model, Model 1, did not include adjustments for any covariates. Model 2 was modified to reflect adjustments for age, gender, and race. Model 3, on the other hand, included adjustments for all conceivable covariates.

The statistical software packages R were utilized to conduct all of the analysis. (http://www.R-project.org, The R Foundation) and Free Statistics software versions 4.3.1.

3. Results

Our comprehensive analysis revealed significant associations between various demographic and behavioral factors with depression status among the studied population, as shown in Table 1. Our dataset comprised 3933 females and 3836 males aged 60 years and older. The prevalence of depression varied significantly across gender, with females and males affected at rates of 7.57% and

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4.73%, respectively. The mean age for participants without depression was 69.68 years (SE±0.14), whereas those with depression were slightly younger, with a mean age of 68.36 years (SE±0.36).

For race/ethnicity, individuals identifying as Hispanic (12.62%) and Non-Hispanic Black (7.41%) exhibited higher rates of depression compared to Non-Hispanic White (5.58%) and other ethnicities (6.40%), indicating notable disparities ($p < 0.0001$). Educational attainment also showed a strong correlation with depression; participants with less than a high school education had a significantly higher incidence of depression (11.59%) compared to those with at least a high school diploma (4.47%) or high school graduates (6.53%).

Marital status was another significant factor; those living alone had a higher prevalence of depression (9.08%) in contrast to those living with others (4.72%), indicating the potential impact of social support on mental health ($p < 0.0001$). Analysis of AHI revealed that individuals with an AHI greater than 75000 had a depression rate of 2.03%, which was lower compared to those with AHI less than 25000 (12.10%) with a p-value of $p < 0.001$.

Recent smoking behaviors were also associated with depression. Current smokers comprised 7.50% of depressed individuals, which was significantly higher than non-smokers (5.00%, $p = 0.002$). Body Mass Index (BMI) categories showed a strong association with depression, with the highest prevalence found in obese individuals (8.45%, $p < 0.0001$).

Furthermore, hypertension and diabetes were more prevalent in the non-depressed group (4,93% and 5.29%, respectively) compared to the depressed group (7.23% and 10.34%, respectively), which may point to the complex interplay between these chronic conditions and mental health (hypertension $p = 0.002$, diabetes $p < 0.0001$).

Sleep duration was also correlated with depression, with those reporting less than 7 hours of sleep showing a higher prevalence of depression (7.13%, $p = 0.01$). Lastly, recent problems with drinking were more prevalent among the depressed (4.82%) compared to those without (0.70%), indicating the significant relationship between alcohol use and depression ($p < 0.0001$).

This table shows the multifaceted nature of depression and highlights the importance of considering a wide range of demographic and lifestyle factors when addressing mental health concerns in older adults.

Table 2. BMI and Depressive Symptoms in Female and Male Subgroups by age categories

	overall	**60-69 years**	**70-79 years**	**80+ years**
BMI:				
Females	29.00±0.16	29.55±0.22	29.35±0.23	26.80±0.21
Males	28.93±0.13	29.34±0.19	28.92±0.20	27.29±0.19
Depression Symptoms:				
Females	374(7.57)	237(9.16)	93(6.13)	44(5.43)
Males	229(4.73)	139(5.50)	64(3.69)	26(3.82)

Note. Means ± standard errors (SE) are presented for continuous variables, counts (weighted percentages) for categorical variables.

In Table 2, the data highlights gender disparities in both Body Mass Index (BMI) and the prevalence of depression symptoms across different age groups. The overall mean BMI was 29.00±0.16 for females and 28.93±0.13 for males, suggesting a marginal difference with females having a slightly higher mean BMI. When examined across age groups, there was a trend of decreasing BMI with increasing age: females aged 60-69 years had a mean BMI of 29.55±0.22, which steadily declined to 26.80±0.21 in those 80 years and older. A similar pattern was observed in males, with those aged 60-69 years having a mean BMI of 29.34±0.19, decreasing to 27.29±0.19 in the 80+ cohort.

Depression symptoms followed a different trend, with a higher prevalence in females (7.57%) compared to males (4.73%) in the overall cohort. Within the age categories, females aged 60-69 years

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had the highest prevalence of depression symptoms (9.16%), which decreased to 5.43% in those 80 years and older. Males aged 60-69 years had a depression prevalence of 5.50%, which also decreased with age to 3.82% in those 80 and older. The data shows a trend of declining depression symptoms as age increases for both sexes, with the decline being more noticeable in women.

Table 3. Association between BMI and depression symptoms

	Model 1 OR(95% CI)	**p-value**	**Model 2 OR(95% CI)**	**p-value**	**Model3 OR(95% CI)**	**p-value**
BMI	1.05(1.03,1.07)	<0.0001	1.04(1.02,1.06)	<0.0001	1.02(1.00,1.05)	0.03
BMI Category						
Underweight	1.78(0.88,3.60)	0.11	1.79(0.87,3.67)	0.11	1.52(0.78,2.98)	0.22
Normal	1.0	ref	1.0	ref	1.0	ref
Overweight	1.00(0.71,1.42)	0.98	1.02(0.72,1.45)	0.90	0.96(0.67,1.36)	0.80
Obese	1.81(1.26,2.60)	0.002	1.71(1.18,2.50)	0.01	1.34(0.94,1.93)	0.11

Model 1: No covariates were adjusted.

Model 2: adjust for: gender; age (smooth); race/ethnicity

Model 3: adjust for: year; gender; age (smooth); race/ethnicity; marital status; AHI; hypertension; diabetes; recent smoking; education levels; recent drinking problem; sleep duration

Table 3 demonstrates how three progressively modified models were used to examine the relationship between body mass index (BMI) and the signs of depression. An odds ratio (OR) of 1.05 (95% Confidence Interval [CI]: 1.03, 1.07; $p < 0.0001$) for Model 1, which did not account for any variables, demonstrated a substantial correlation and showed that there was a 5% increase in the likelihood of depression symptoms for every unit rise in BMI.

Upon adjustment for gender, age, and race/ethnicity in Model 2, the association remained significant, albeit slightly attenuated, with an OR of 1.04 (95% CI: 1.02, 1.06; $p < 0.0001$). This suggests that demographic factors do mediate the relationship between BMI and depression, but a significant independent effect of BMI persists.

In Model 3, which included a comprehensive set of covariates—year, gender, age (smooth), race/ethnicity, marital status, AHI, hypertension, diabetes, recent smoking, education levels, recent drinking problem, and sleep duration—the association was further attenuated yet remained significant (OR = 1.02; 95% CI: 1.00, 1.05; $p = 0.03$). This indicates that while the effect size of BMI on depression is reduced when controlling for these variables, there is still a discernible impact of BMI on depression outcomes.

If we treat BMI as a category variable, the three models give different results. In Model 1, which does not adjust for any covariates, both underweight and obese categories show increased odds of depression symptoms compared to the normal BMI category, with obese individuals having significantly higher odds (OR 1.81, 95% CI [1.26,2.60], p=0.002). In Model 2, the association between obesity and depression remains significant (OR 1.71, 95% CI [1.18,2.50], p=0.01), while the association for the underweight category is not significant (p=0.11). In contrast, the odds for obese individuals are still higher but the association is no longer significant (OR 1.34, 95% CI [0.94,1.93], p=0.11) in Model 3. This indicates that the covariates added in Model 3 can explain some of the relationships between BMI and depression.

The generalized additive model (GAM) shown in Figure 2 illustrates the U-shaped relationship between body mass index (BMI) and sign of depressive. The analysis accounts for a series of covariates, including gender, age (adjusted using a smoothing function), race/ethnicity, marital status,

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AHI, hypertension, diabetes, recent smoking habits, education levels, recent drinking problems, and sleep duration. The red line in the graph denotes the smoothed mean estimate of the probability of depressive symptoms across the BMI spectrum, while the shaded area indicates the 95% confidence interval. The U-shaped curve suggests that both lower and higher values of BMI are linked to an increased likelihood of experiencing symptoms of depression, with the nadir occurring in the intermediate BMI range. This pattern persists even after adjusting for the listed confounding variables, suggesting a complex and potentially bidirectional relationship between body weight and mental health.

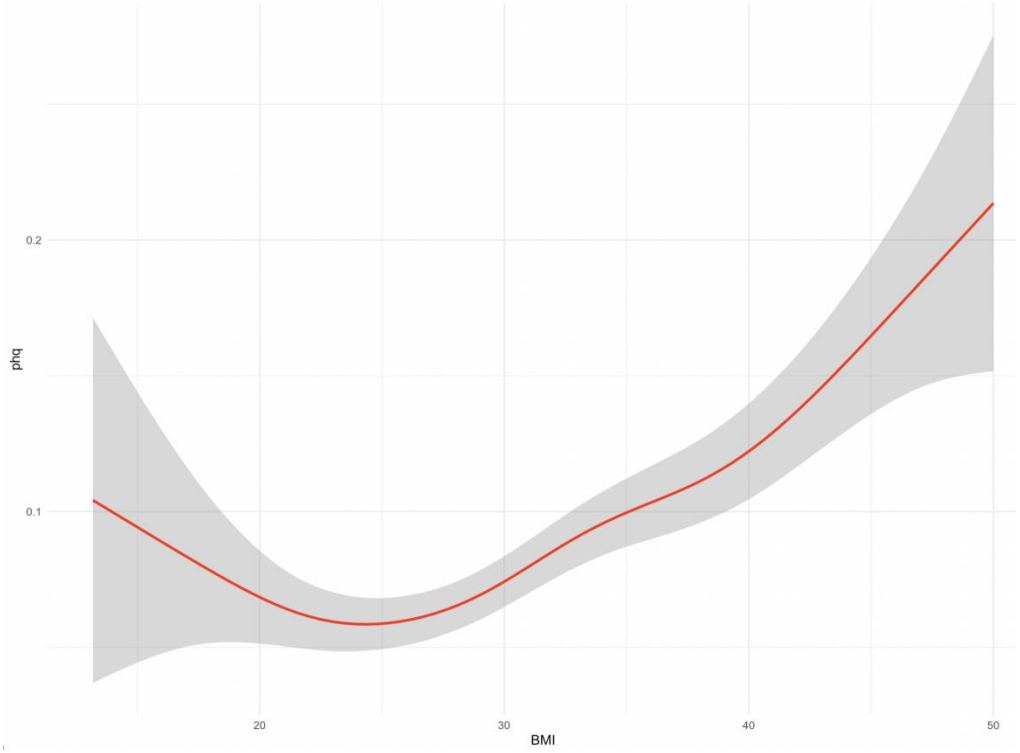

Figure 2. GAM

The relationship between depressive symptoms and BMI, after adjusting year; gender; age (smooth); race/ethnicity; marital status; AHI; hypertension; diabetes; recent smoking; education levels; recent drinking problem; sleep duration.

4. Discussion

In order to investigate the association between Body Mass Index (BMI) and the prevalence of depressive symptoms among American adults, we conducted a community-based cross-sectional investigation for this study. Utilizing a strong methodological framework, we gathered and examined data from a wide range of participants in various communities. According to our research, there is a U-shaped curve in the relationship between BMI and depressed symptoms, meaning that there is a higher risk of depression associated with both lower and higher BMI extremes. The constant observation of this tendency across multiple demographic groups suggests that it is a universal trend, independent of factors such as age, gender, or financial situation. Notably, our findings support a previous study's conclusion that there is a complex and nonlinear association between them. Similar to the previous study, this one also found a U-shaped correlation, indicating that being underweight and being obese may be risk factors for depression. By offering additional empirical data from a wider and more diverse American population, our study expands on these findings and emphasizes the

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significance of taking BMI into account when conducting mental health examinations and interventions.[13].

Our results corroborate the significant, independent relationship between depression and BMI. This study provides more evidence that numerous mental health issues and physical conditions in older persons are connected due to their biopsychosocial character. Our research highlights the potential usefulness of depression and BMI measurements in evaluating changes in the mental and physical well-being of older individuals who live in the community.

Previous studies shown that the relationship between depression and obesity is bidirectional. While research from Western nations typically indicates a positive correlation between obesity and depression, studies from Asian regions like China and Korea have demonstrated a negative correlation amongst the elderly population [14-15]. A potential reason for the disparate findings could be that factors like gender, age, socio-economic background, ethnic identity, citizenship and particularly culture, influence the connection between obesity and depressive disorders. Last but not least, other psychiatric disorders should also be explored in future research, as previous studies have revealed that not only depression is associated with obesity, but other psychiatric disorders are also associated with obesity [16].

In the study, we can see that the obese people and the lean people both have a higher odds ratio than the normal people. This may be caused by social attributes, as they are more likely to experience weight discrimination [17]. This implies that society ought to assist obese individuals more and normalize the attitude of the general public toward obesity. In addition, poor eating patterns (including those that follow sadness), behavioral disorders, and adverse medical or socioeconomic circumstances are linked to depression.

This research is subject to certain constraints. Initially, the data collection relied on self-administered questionnaires and subjective self-reporting, which could introduce errors stemming from misremembering or biased reporting. Additionally, the efficacy of BMI as an indicator of body fat has been a topic of debate. While BMI is commonly used to evaluate weight in the general populace, it may not accurately reflect levels of visceral fat, which can be either overestimated or underestimated.

5. Conclusion

In summary, there is a significant correlation between both underweight and overweight conditions and depression, exhibiting a U-curve association with Body Mass Index (BMI). Further research is warranted to investigate the connection between body weight aspects, such as visceral fat and its distribution, and depression. As this research is a cross-sectional study, we can not explore the causal link between BMI and depression. This needs further study. Also, the relationship can be temporally, as the data are not collected longitudinally. For the results of the 3 model, some of the odds ratios have a really high p-value, which indicates that there is some interaction or correlation between the selected covariates, which needs more consideration. Furthermore, the sample may not represent the whole population well, as selecting participants may have bias. And not all the potential confounders have been included in the analysis.

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