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Visceral Adiposity Index Is a Measure of the Likelihood of Developing Depression Among Adults in the United States

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Background: Depression is a serious mental disorder often accompanied by emotional and physiological disorders. Visceral fat index (VAI) is the current standard method in the evaluation of visceral fat deposition. In this study, we explored the association between VAI and depression in the American population using NHANES data.

Methods: A total of 2,577 patients were enrolled for this study. Data were collected through structured questionnaires. Subgroup analysis for the relationship between VAI and depression was evaluated using multivariate regression analysis after adjustment for potential confounding factors.

Results: For every 1 unit increase in VAI, the clinical depression increased by 14% (OR = 1.14, 95% CI: 1.04–1.25). High VAI scores (T3) increased the highest risk of developing depression (OR = 2.32, 95% CI: 1.2–4.47). Subgroup analysis demonstrated a strong and stable association between VAI and the development of depression.

Conclusion: Our study showed that depressive symptoms are associated with a high ratio of visceral adiposity index after controlling confounding factors.

Keywords: NHANES, depressive symptoms, depression, visceral adiposity index (VAI), visceral adiposity

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BACKGROUND

Depression is a serious mental disorder often accompanied by emotional and physiological disorders (Nguyen et al., 2017; Jackson et al., 2019). Based on the WHO data, there are more than 300 million people with depression worldwide (Puttige Ramesh et al., 2019). In the United States, 16% of people suffer depression at least once in their lifetime (Kessler et al., 2003). Depression usually occurs alongside other chronic diseases. The 15-year recurrence rate of depression in the general population is 35% (Hoen et al., 2010).

Obesity has been implicated in the development of depression (Heo et al., 2006; Rivenes et al., 2009; Luppino et al., 2010; Linde et al., 2011; Haynes et al., 2019). This is evidenced by how the outcome of depression with underlying obesity relies on treatment-seeking behavior (Felitti, 1993). Body mass index (BMI) is a reliable indicator of obesity. In addition, high BMI in adulthood

has been linked with depression (Hoen et al., 2010; Mannan et al., 2016). Obesity based on BMI has been linked with the risk of developing depression (Heo et al., 2006; Rivenes et al., 2009; Luppino et al., 2010; Linde et al., 2011; Haynes et al., 2019). However, given that BMI cannot distinguish between visceral fat from fat mass, it is not an accurate measure of obesity (Huang et al., 2019; Yang S. J. et al., 2020; Favre et al., 2021). In related research, the measure of waist circumference (WC), which reflects the level of visceral fat, was found to be positively correlated with depression (Heo et al., 2006). However, just like BMI, WC does not discriminate visceral adipose tissue from abdominal subcutaneous fat (Heo et al., 2006; verson-Rose et al., 2009).

Deposition of visceral fats is associated with high circulating TNF-α and IL-6 and a decrease in insulin sensitivity (Lin et al., 2013; Yang J. et al., 2020). Visceral fats can independently predict the development of depression (Vogelzangs et al., 2008). High visceral fat at baseline, based on CT scan, has been linked with depression (Alshehri et al., 2019). Although imaging techniques such as CT and MRI can directly measure the amount of visceral fat, they cannot be routinely used due to safety and economical limitations. Currently, the visceral adiposity index (VAI) can accurately reflect the accumulation of visceral fats (Amato et al., 2010). Therefore, we explored the relationship between VAI and the development of depression using the National Health and Nutrition Examination Survey (NHANES) data for adults in the United States (US) population.

MATERIALS AND METHODS

Study Design and Data Collection

The National Health and Nutrition Examination Survey (NHANES) was a cross-sectional survey on adults in the US. The study was approved by The Research Ethics Review Board of the National Center for Health Statistics. Data were collected by trained staff through clinical examinations and structured questionnaires. The NHANES data is available at https://www.cdc.gov/nchs/nhanes/default.aspx.

Study Sample

The data were collected from 2013 to 2014 and comprised 9,422 individuals, of which 2,577 were further sampled for interviews. All participants consented to participate in the research. Patients under 18 years of age and those with missing data were excluded from the study. The inclusion and exclusion criteria are summarized in **Figure 1**.

Assessment of Primary Variables

Scores for Depression

Depression scores within 2 weeks of the interview were calculated using a diagnostic module, the 9-question Patient Health Questionnaire (PHQ-9), as described in earlier studies (2005–2016) (Patel et al., 2019). PHQ-9 scores $\geq$ 10 were indicative of depression (Jackson et al., 2019).

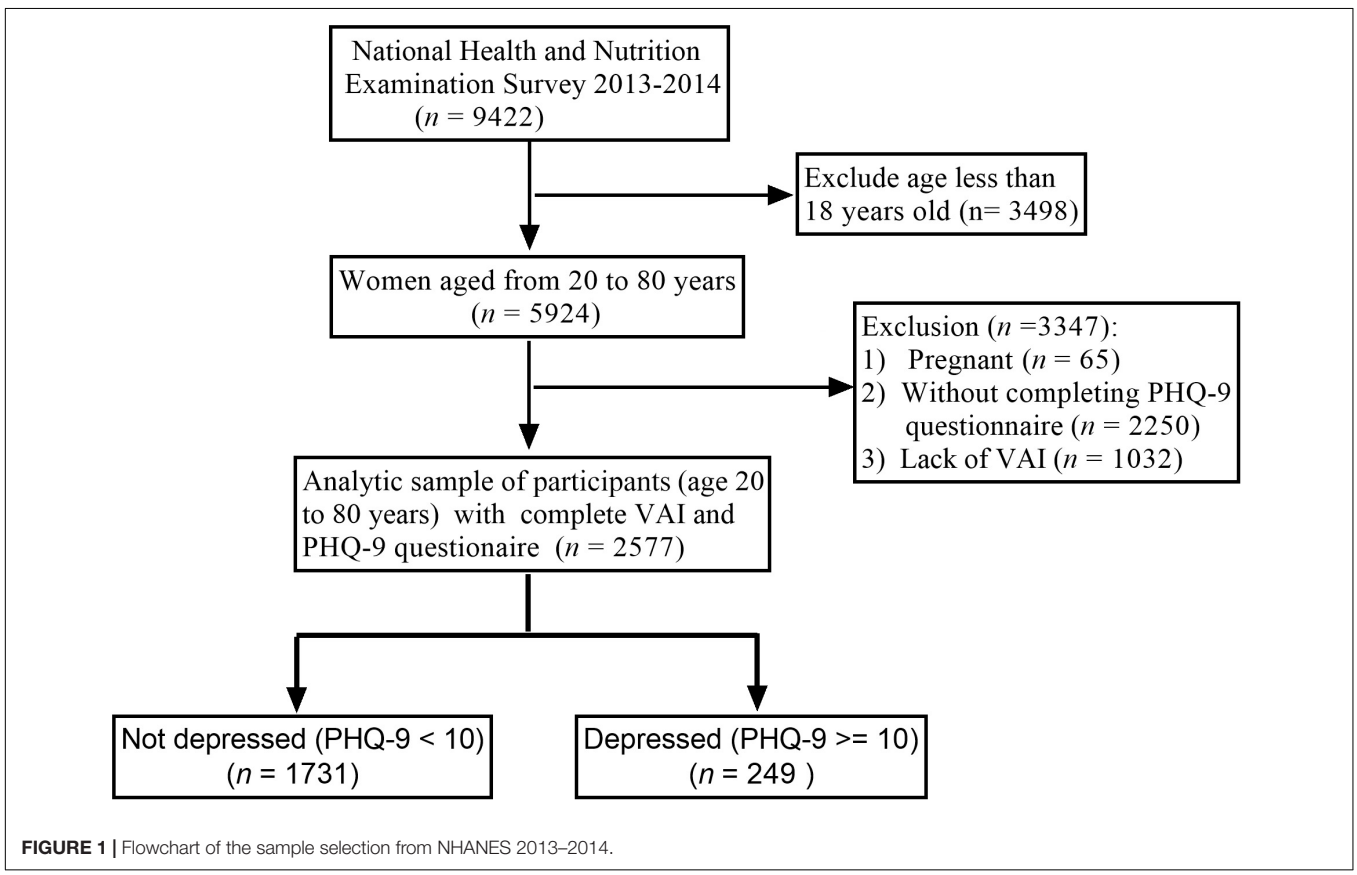

FIGURE 1 | Flowchart of the sample selection from NHANES 2013–2014.

TABLE 1 | Baseline characteristics of the cohort (*N* = 2,577).

Characteristics	Visceral adiposity index				*P*-value
	Total (*n* = 2,577)	T1 (*n* = 859)	T2 (*n* = 859)	T3 (*n* = 859)	
Age, year	47.58 ± 18.17	43.85 ± 18.91	48.72 ± 18.01	50.18 ± 16.94	<0.001
BMI, kg/m^2	28.80 ± 7.19	26.03 ± 6.26	28.90 ± 7.14	31.46 ± 7.09	<0.001
Waist circumference, cm	98.31 ± 16.90	90.24 ± 15.09	98.72 ± 16.22	105.96 ± 15.59	<0.001
Gender					0.296
Male	1,241 (48.16%)	431 (50.17%)	399 (46.45%)	411 (47.85%)	
Female	1,336 (51.84%)	428 (49.83%)	460 (53.55%)	448 (52.15%)	
Race					<0.001
Mexican American	348 (13.50%)	80 (9.31%)	124 (14.44%)	144 (16.76%)	
Other Hispanic	232 (9.00%)	66 (7.68%)	81 (9.43%)	85 (9.90%)	
Non-Hispanic white	1,129 (43.81%)	343 (39.93%)	366 (42.61%)	420 (48.89%)	
Non-Hispanic black	498 (19.32%)	238 (27.71%)	162 (18.86%)	98 (11.41%)	
Other race	370 (14.36%)	132 (15.37%)	126 (14.67%)	112 (13.04%)	
Education level (n,%)					<0.001
Less than 9th grade	182 (7.48%)	43 (5.56%)	59 (7.17%)	80 (9.56%)	
9–11th grade	357 (14.67%)	96 (12.40%)	117 (14.22%)	144 (17.20%)	
High school graduate or equivalent	519 (21.32%)	154 (19.90%)	188 (22.84%)	177 (21.15%)	
Some college or AA degree	738 (30.32%)	229 (29.59%)	247 (30.01%)	262 (31.30%)	
College graduate or above	635 (26.09%)	250 (32.30%)	212 (25.76%)	173 (20.67%)	
Marital status (*n*,%)					<0.001
Married	1,315 (54.03%)	403 (52.07%)	460 (55.89%)	452 (54.00%)	
Widowed	167 (6.86%)	49 (6.33%)	53 (6.44%)	65 (7.77%)	
Divorced	260 (10.68%)	60 (7.75%)	95 (11.54%)	105 (12.54%)	
Separated	71 (2.92%)	20 (2.58%)	24 (2.92%)	27 (3.23%)	
Never married	438 (18.00%)	181 (23.39%)	139 (16.89%)	118 (14.10%)	
Living with partners	183 (7.52%)	61 (7.88%)	52 (6.32%)	70 (8.36%)	
Smoking status					<0.001
Never smoker	1,490 (57.82%)	555 (64.61%)	487 (56.69%)	448 (52.15%)	
Current smoker	510 (19.79%)	131 (15.25%)	174 (20.26%)	205 (23.86%)	
Former smoker	577 (22.39%)	173 (20.14%)	198 (23.05%)	206 (23.98%)	
Drinking					0.251
No	575 (22.31%)	193 (22.47%)	200 (23.28%)	182 (21.19%)	
Yes	1,696 (65.81%)	570 (66.36%)	568 (66.12%)	558 (64.96%)	
Self-reported chronic diseases					
Heart failure	75 (3.08%)	17 (2.20%)	22 (2.67%)	36 (4.30%)	0.036
Coronary heart disease	95 (3.90%)	18 (2.33%)	30 (3.65%)	47 (5.62%)	0.016
Angina/angina pectoris	55 (2.26%)	11 (1.42%)	21 (2.55%)	23 (2.75%)	0.129
Heart attack	92 (3.78%)	23 (2.97%)	29 (3.52%)	40 (4.78%)	0.310
Stroke	82 (3.37%)	24 (3.10%)	27 (3.28%)	31 (3.70%)	0.623
Chronic bronchitis	135 (5.55%)	30 (3.88%)	39 (4.74%)	66 (7.89%)	0.003
Hypertension	849 (92.58%)	202 (89.38%)	276 (93.56%)	371 (93.69%)	0.106
Hypercholesterolemia	873 (33.88%)	184 (21.42%)	305 (35.51%)	384 (44.70%)	<0.001
Diabetes					<0.001
No	2,221 (86.19%)	800 (93.13%)	749 (87.19%)	672 (78.23%)	
Yes	277 (10.75%)	39 (4.54%)	88 (10.24%)	150 (17.46%)	
Borderline	79 (3.07%)	20 (2.33%)	22 (2.56%)	37 (4.31%)	
Family PIR	2.05 (1.02–4.05)	2.21 (1.03–4.35)	2.20 (1.06–4.19)	1.79 (0.97–3.55)	<0.001
HDL-cholesterol (mmol/L)	1.39 ± 0.41	1.70 ± 0.44	1.37 ± 0.29	1.10 ± 0.25	<0.001
Triglyceride (mmol/L)	1.05 (0.72,1.59)	0.63 (0.50–0.74)	1.05 (0.90–1.22)	1.93 (1.53–2.57)	<0.001
LDL-cholesterol (mmol/L)	2.85 ± 0.91	2.58 ± 0.78	2.93 ± 0.87	3.04 ± 1.01	<0.001
Total cholesterol (mmol/L)	4.84 ± 1.07	4.56 ± 0.95	4.79 ± 0.99	5.15 ± 1.18	<0.001

(Continued)

TABLE 1 | (Continued)

Characteristics	Visceral adiposity index				*P*-value
	Total (*n* = 2,577)	T1 (*n* = 859)	T2 (*n* = 859)	T3 (*n* = 859)	
Glycohemoglobin (%)	5.70 ± 1.03	5.44 ± 0.63	5.67 ± 0.94	5.99 ± 1.31	<0.001
Dietary intake					
Energy, kcal	1,964 (1,439, 2,575)	2,036 (1,479, 2,652)	1,953 (1,434.5, 2,535)	1,907 (1,398.5, 2,566)	0.013
Protein, gm	75.75 (53.46, 103.85)	80.78 (56.95, 108.43)	73.40 (52.39, 98.79)	74.47 (51.62, 105.22)	0.001
Carbohydrate, gm	230.81 (163.84, 312.13)	234.10 (163.87, 315.90)	228.49 (165.12, 309.04)	229.90 (161.97, 315.49)	0.382
Total fat, gm	74.24 (49.72, 104.05)	74.95 (53.93, 106.54)	76.52 (48.87, 101.70)	71.82 (47.17, 103.32)	0.037
Cholesterol, gm	237 (136–409)	245 (145, 403)	222 (131, 399.5)	238 (131, 423.5)	0.299
Visceral adiposity index	1.27 (0.76, 2.19)	0.61 (0.47, 0.76)	1.27 (1.09, 1.49)	2.79 (2.19, 4.08)	<0.001
Depressive symptoms					<0.001
<10	1371 (84.63%)	454 (88.85%)	472 (87.73%)	445 (77.93%)	
> = 10	249 (15.37%)	57 (11.15%)	66 (12.27%)	126 (22.07%)	

Visceral Adiposity Index Score

The VAI is a gender-specific measure of visceral fat distribution and function based on anthropometric (BMI and WC) and metabolic parameters [high-density lipoprotein cholesterol (HDL-c) and triglycerides] (Amato et al., 2010; Ferguson et al., 2021). The VAI formulae for men and women are shown in **Supplementary Table 1**. Research shows that the VAI score is directly proportional to the amount of deposited visceral fats (Amato et al., 2010; Ferguson et al., 2021). According to the VAI of individuals in the baseline, three groups (trisection) were categorized as T1: low (0.11–0.92), T2: middle (0.93–1.79), and T3: high (> 1.79).

Assessment of Study Variables

The potential confounding factors of depression, such as gender, age, race, education level, marital status, diabetes mellitus, family income-to-poverty ratio (PIR), self-reported chronic diseases, WC, BMI, smoking status, dietary intake in a 24-h period, triglycerides, HDL-c, total cholesterol, Vitamin D, glycohemoglobin, low-density lipoprotein cholesterol (LDL-c), and fasting blood glucose, were selected based on previous studies. Triglycerides, total cholesterol, glycohemoglobin, and fasting blood glucose were measured using the NHANES laboratory protocol. Level of education was categorized into several groups, namely, college graduate or above, college or associate (AA) degree, high school graduate, and below 11th grade. Regarding race, the participants were classified into Mexican-American, non-Hispanic black, non-Hispanic white, Hispanic, and others. Marital status included married, living with a partner, never married, divorced, widowed, or separated. Family income-to-poverty ratio was expressed as previously described in which the household income was divided by the poverty threshold. All participants were interviewed two times regarding 24-h feeding habits. The first dietary interviews, which included protein, energy, total sugars, carbohydrate, fibers, and total fat intake, were conducted at the Mobile Examination Center (MEC). Alcohol consumption and smoking were assessed as previously described (Patel et al., 2019). Hypertension was screened based on medical reports or intake of antihypertensive drugs. Hypercholesterolemia was evaluated according to a cholesterol test or previous diagnosis.

Statistical Analysis

Continuous variables were presented as means, standard errors, percentages, or frequencies. Differences between categorical variables were analyzed using the chi-square test, whereas differences between continuous variables were evaluated using ANOVA or the Man-Whitney *U*-tests based on the nature of the distribution. The association between VAI quartiles and depression was expressed using three models. For Model I, there was no adjustment for confounding factors. In Model II, there were adjustments for age, gender, alcohol drinking, diabetes, smoking status, history of specific diseases, educational status, race, marital status, and family PIR. Categorical variables associated with VAI were converted into continuous variables using the models before analysis. Stratified interaction analyses were performed based on all variables outlined in **Table 1**. Data were analyzed using Empower-Stats and R software.[1] A two-sided value of $p < 0.05$ was considered statistically significant.

RESULTS

Patient Characteristics at Baseline

Data for patients (n = 2,577) included in the final analysis are shown in **Figure 1**, whereas patient characteristics at baseline are shown in **Table 1**. Overall, the mean age of the participants was 47.58 (SD = 18.17) years. Also, 51.84% of the participants

[1] http://www.R-project.org

TABLE 2 | Univariate analysis for depressive symptoms.

Characteristics	Statistics	OR, 95%CI, *P*-value
Age, year	47.58 ± 18.17	1.01 (1.01, 1.02)< 0.001
BMI, kg/m^2	28.80 ± 7.19	1.05 (1.03, 1.06)< 0.001
Waist circumference, cm	98.31 ± 16.90	1.02 (1.01, 1.03)< 0.001
Gender		
Male	1,241 (48.16%)	1.0
Female	1,336 (51.84%)	1.41 (1.07, 1.87) 0.016
Race		
Mexican American	348 (13.50%)	1.0
Other Hispanic	232 (9.00%)	0.93 (0.53, 1.63) 0.796
Non-Hispanic white	1,129 (43.81%)	0.91 (0.61, 1.37) 0.665
Non-Hispanic black	498 (19.32%)	1.00 (0.63, 1.60) 0.993
Other race	370 (14.36%)	0.44 (0.24, 0.82) 0.009
Education level (n,%)		
Less than 9th grade	182 (7.48%)	1.0
9–11th grade	357 (14.67%)	0.61 (0.35, 1.05) 0.076
High school graduate or equivalent	519 (21.32%)	0.53 (0.31, 0.90) 0.018
Some college or AA degree	738 (30.32%)	0.52 (0.31, 0.86) 0.011
College graduate or above	635 (26.09%)	0.24 (0.13, 0.42) < 0.001
Marital status (*n*,%)		
Married	1,315 (54.03%)	1.0
Widowed	167 (6.86%)	2.43 (1.50, 3.91)< 0.001
Divorced	260 (10.68%)	2.83 (1.91, 4.20)< 0.001
Separated	71 (2.92%)	2.63 (1.32, 5.26) 0.006
Never married	438 (18.00%)	1.11 (0.74, 1.68) 0.610
Living with partners	183 (7.52%)	1.23 (0.70, 2.15) 0.466
Smoking status		
Never smoker	1,490 (57.82%)	1.0
Current smoker	510 (19.79%)	1.74 (1.25, 2.41) < 0.001
Former smoker	577 (22.39%)	1.35 (0.96, 1.88) 0.081
Drinking		
No	575 (22.31%)	1.0
Yes	1,696 (65.81%)	0.94 (0.65, 1.36) 0.750
Self-reported chronic diseases		
Heart failure	75 (3.08%)	2.43 (1.35, 4.36) 0.003
Coronary heart disease	95 (3.90%)	2.50 (1.47, 4.25)< 0.001
Angina/angina pectoris	55 (2.26%)	1.13 (0.52, 2.44) 0.764
Heart attack	92 (3.78%)	2.18 (1.25, 3.83) 0.006
Stroke	82 (3.37%)	1.19 (0.61, 2.33) 0.602
Chronic bronchitis	135 (5.55%)	3.83 (2.51, 5.83)< 0.001
Hypertension	849 (92.58%)	1.30 (0.56, 3.02) 0.539
Hypercholesterolemia	873 (33.88%)	1.51 (1.14, 1.98) 0.004
Diabetes		
No	2,221 (86.19%)	1.0
Yes	277 (10.75%)	1.94 (1.35, 2.81)< 0.001
Borderline	79 (3.07%)	1.76 (0.91, 3.41) 0.091
Family PIR	2.05 (1.02–4.05)	0.73 (0.66, 0.81)< 0.001
HDL-cholesterol (mmol/L)	1.39 ± 0.41	0.73 (0.52, 1.04) 0.083
Triglyceride (mmol/L)	1.05 (0.72–1.59)	1.06 (0.99, 1.14) 0.106
LDL-cholesterol (mmol/L)	2.85 ± 0.91	1.10 (0.95, 1.28) 0.202
Total cholesterol (mmol/L)	4.84 ± 1.07	1.12 (1.00, 1.27) 0.058
Glycohemoglobin (%)	5.70 ± 1.03	1.22 (1.10, 1.36) 0.001
Dietary intake		
Energy, kcal	1,964 (1,439–2,575)	1.00 (1.00, 1.00) 0.374
Protein, gm	75.75 (53.46–103.85)	0.99 (0.99, 1.00)< 0.001
Carbohydrate, gm	230.81 (163.84–312.13)	1.00 (1.00, 1.00) 0.386
Total fat, gm	74.24 (49.72–104.05)	1.00 (1.00, 1.00) 0.366
Cholesterol, mg	237 (136–409)	1.00 (1.00, 1.00) 0.001
Visceral adiposity index	1.27 (0.76–2.19)	1.04 (1.00, 1.08) 0.047
Visceral adiposity index		
T1	859 (33.33%)	1.0
T2	859 (33.33%)	1.11 (0.76, 1.62) 0.576
T3	859 (33.33%)	2.26 (1.61, 3.17) < 0.001

were female and 49.16% were male. Based on the baseline results of VAI of the three groups (trisection: T1, T2, T3), high VAI (T3) was associated with older age, other Hispanic and non-Hispanic white race, wider WC, low total energy, protein, and fat intake, depression, less educated, high family PIR, divorce, widowed, separated or living with partners, active or history of smoking, history of heart failure, coronary heart disease, chronic bronchitis, diabetes, and hypercholesterolemia than T1 and T2 group ($p < 0.05$). Low VAI scores were more associated with depression, hypertension, young/older age, high/low total cholesterol, and HDL-c than T2 and T3 group ($p < 0.05$).

Relationship Between Visceral Fat Index Score and Depression

We observed a significant difference in VAI, age, BMI, WC, gender, race, education level, marital status, smoking status, family PIR, glycohemoglobin, and dietary intake ($p < 0.05$) between depressed and non-depressed individuals (**Table 2**). Comparable findings were observed for heart failure, coronary heart disease, heart attack, chronic bronchitis, hypercholesterolemia, and diabetes. However, high VAI (T3) is significantly related to depressed individuals compared with non-depressed individuals (OR = 2.26, 95% CI:1.61–3.17, $p < 0.01$).

The Relationship Between Visceral Fat Index Scores and Depression After Adjustment for Confounding Factors

The relationship between VAI scores and depression was described using three models before and under adjustment for potential confounders (**Table 3**). After adjustment for all cofounding factors, Model III revealed that every 1 unit increase in VAI increased the likelihood of developing depression by 14% (OR = 1.14, 95% CI: 1.04–1.25). We found comparable findings even after converting continuous variables to categorical variables. Model III also revealed that VAI positively correlated with the risk of developing depression.

Sub-group analyses revealed that age, gender, marital status, diabetes, hypertension, hypercholesterolemia, drinking, race, education level, family PIR, marital status, and smoking status had no significant effect on the association between VAI and development of depression (all at $p < 0.05$) (**Table 4**).

TABLE 3 | Relationship between visceral adiposity index and depressive symptoms in different models.

Exposure	OR (95%CI), *P*-value		
	Model 1	Model 2	Model 3
Visceral adiposity index	1.04 (1.00, 1.08) 0.047	1.04 (1.00, 1.08) 0.048	1.14 (1.04, 1.25) 0.004
Visceral adiposity index			
T1	1.0	1.0	1.0
T2	1.11 (0.76, 1.62) 0.575	1.04 (0.71, 1.51) 0.858	1.00 (0.74, 1.51) 0.858
T3	2.26 (1.61, 3.17) < 0.001	2.10 (1.49, 2.96) < 0.001	2.32 (1.20, 4.47) 0.012
P for trend	< 0.001	<0.001	0.001

Model 1, adjust for none.
Model 2, adjust for age, gender.
Model 3, adjust for age, gender, drinking, diabetes, smoking status, Self-reported chronic diseases, educational level, race, marital status, family PIR.

DISCUSSION

Herein, we observed a strong and stable positive correlation between VAI and the development of depression in both men and women. After controlling for confounding factors, clinically significant depressive symptoms were found to be associated with VAI. For every one-unit increase in VAI, the clinical depression increased by 14%. High VAI scores (T3) increased the highest risk of developing depression compared with the T1 group. Subgroup analysis demonstrated a strong and stable association between VAI and the development of depression.

Body mass index (BMI) has been liked with obesity and WC. In addition, it is the main clinical parameter for indirect assessment of visceral fat level. However, Yang et al. found that abdominal sagittal diameter (SAD) is a non-invasive method of measuring visceral fat content and predicts the development of depression more accurately than BMI (Zhou et al., 2020). Recent studies found that SAD and BMI cannot discriminate between subcutaneous and visceral fat mass. The VAI is based on metabolic (HDL-C and TG) and anthropometric (WC and BMI) parameters (Amato et al., 2010). Using CT scanning, Vogelzangs et al. (2008) found that the level of visceral adipose tissue is positively correlated with the likelihood of developing depression. A cross-sectional study reported that there is remarkable variation in VAI scores for any given BMI value (Du et al., 2014). We found a strong positive correlation between VAI and depressive symptoms in both men and women. The relationship between the high VAI group and depression is stronger than in the low (T1) and middle (T2) VAI groups. It also confirmed prior studies' findings that depressive symptoms are associated with intra-abdominal fat and the ratio of visceral and total adipose area.

Depression is heterogeneous disorder (Benazzi, 2006; Du et al., 2014). Studies show that VAI reflects the deposition degree of adipose tissues and is an accurate surrogate marker for "adipose tissue function" (Numan Ahmad and Halim Haddad, 2015). In a related study, Alshehri et al. (2019) reported that the degree of obesity is positively correlated with depression. Adiposity is related to immune and metabolic dysregulations. Meanwhile, high visceral fat increases the activity of pro-inflammatory factors (Amato et al., 2010) and the development of depression (Yang J. et al., 2020). In addition, the visceral fat quality and VAI reflect the severity of coronary heart disease in patients with diabetes and coronary heart disease (Yang J. et al., 2020). In this study, we found high VAI scores strongly and positively correlated with the development of depression.

Visceral fat index (VAI) is more pathogenic than subcutaneous adiposity because of its greater endocrine activity. It is suggested that VAI is a measure of visceral fat function and a marker for cardio-metabolic disorders that is more accurate and sensitive than traditional parameters, such as WC, BMI, and blood lipid assessment (Amato et al., 2010). High visceral fat disrupts adipokinesis, which may lead to numerous metabolism-related disorders (Arai et al., 2011). Several hypotheses have been proposed to describe the

TABLE 4 | Results of subgroup analysis and interaction analysis.

Characteristic	No. of participates	OR (95%CI)	*P* for interaction
Age, year			0.1907
18–36	816	0.96 (0.84, 1.11) 0.6014	
37–56	880	1.04 (0.99, 1.09) 0.1134	
57–80	881	1.13 (1.00, 1.28) 0.0566	
Gender			0.4075
Male	1,241	1.06 (1.00, 1.12) 0.0423	
Female	1,336	1.03 (0.99, 1.07) 0.1969	
Diabetes			
No	2,221	1.07 (1.01, 1.12) 0.0166	
Yes	277	1.01 (0.96, 1.05) 0.8183	
Hypertension			0.7276
No	68	1.20 (0.88, 1.64) 0.2502	
Yes	849	1.13 (1.05, 1.22) 0.0009	
Hypercholesterolemia			0.1047
No	1,686	1.07 (1.00, 1.14) 0.0390	
Yes	873	1.02 (0.98, 1.06) 0.2880	
Smoking status			0.5638
Never smoker	1,490	1.03 (0.99, 1.07) 0.2059	
Current smoker	510	1.04 (0.96, 1.12) 0.3394	
Former smoker	577	1.09 (0.99, 1.20) 0.0877	
Drinking			0.0806
No	575	1.01 (0.96, 1.06) 0.8009	
Yes	1,696	1.07 (1.02, 1.12) 0.0073	
Race			0.0722
Mexican American	348	1.03 (0.89, 1.18) 0.7288	
Other Hispanic	232	1.00 (0.93, 1.07) 0.8939	
Non-Hispanic white	1,129	1.08 (1.02, 1.14) 0.0086	
Non-Hispanic black	498	1.00 (0.75, 1.32) 0.9820	
Other race	370	1.18 (1.04, 1.34) 0.0094	
Family PIR			0.1000
0–1.26	787	1.10 (1.03, 1.17) 0.0063	
1.27–3.2	800	1.01 (0.96, 1.06) 0.7719	
3.22–5	802	1.04 (0.93, 1.15) 0.4984	
Marital status (*n*,%)			0.3495
Married	1,315	1.02 (0.98, 1.06) 0.3370	
Widowed	167	1.33 (1.00, 1.78) 0.0536	
Divorced	260	1.07 (0.96, 1.19) 0.2205	
Separated	71	1.02 (0.90, 1.15) 0.8075	
Never married	438	1.14 (0.98, 1.33) 0.1005	
Living with partners	183	1.08 (0.94, 1.24) 0.2686	

relationship between intraperitoneal fat level and depression. First, high cortisol is thought to increase the risk of developing metabolic syndrome and depression (van Santen et al., 2011). Second, depression was thought to result from inflammation (Milaneschi et al., 2019). Visceral obesity is associated with levels of serum inflammatory cytokine and insulin sensitivity. Third, insulin resistance is thought to increase the risk of developing metabolic disorders, dyslipidemia, and depression (Jokela et al., 2014). Although insulin levels were not measured, a low insulin level is a risk factor for developing depression. Our findings notwithstanding, the relationship between insulin resistance, VAI, and depression needs further investigation.

STRENGTHS AND LIMITATIONS

Regarding strengths, first, VAI is an accurate method of estimating visceral obesity in addition to it being cheap and safe. Second, the data were large and representative of the American population. However, the self-evaluation approach without additional psychotic assessment did not reveal the specific type of depression. Third, the majority of the participants were American adults. As such, the findings of this study in the context of other ethnic groups should be interpreted with caution. Fourth, the possible interference effect of other non-traditional risk factors for depression such as inflammatory markers were not investigated. Lastly, due to the cross-sectional study, some of the risk factors, such as major cardiovascular events, were not observed. We also could not investigate the causal connection between VAI and depression as well.

CONCLUSION

VAI positively correlates with the likelihood of developing depression. As such, visceral fat must be maintained within a certain range to minimize the chances of developing depression.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Research Ethics Review Board of National Center for Health Statistics. The participants provided their written informed consent to participate in the study.

AUTHOR CONTRIBUTIONS

JL and YL provided methodological expertise and revised the article. YX, YL, and JL conceived the manuscript and drafted the manuscript. XW drafted the tables and figures. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.772556/full#supplementary-material

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