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Association between cardiometabolic index (CMI) and suicidal ideation
A cross-sectional analysis of NHANES 2005 to 2018 data

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Abstract
With suicide ranking as a leading cause of death globally, identifying modifiable risk factors is crucial. Suicidal ideation (SI) is a significant precursor to suicide, and there is a growing interest in the role of cardiometabolic factors, particularly the cardiometabolic index (CMI), multiplying the triglyceride-to-high-density lipoprotein cholesterol ratio by the waist-to-height ratio, in mental health outcomes. Previous studies have shown a notable relationship among lipid abnormalities, elevated triglyceride levels, and depressive symptom severity, including SI. This research investigated the correlation between the CMI levels of adult Americans and SI, utilizing data from the National Health and Nutrition Examination Survey (NHANES) ranging from the years 2005 to 2018. After collecting data on demographics, physical examinations, and laboratory testing, multivariate logistic regression analysis was conducted to assess the relationship between CMI and SI while adjusting for relevant factors. The study, which enrolled 15,849 individuals exhibiting symptoms of SI, constituting 3.47% of the total, revealed a significant association between CMI levels and SI. A significant positive association was found between CMI and SI (adjusted OR = 1.07, 95% CI: 1.02–1.13, *P* = .0029). Moreover, a nonlinear relationship was identified between CMI and SI, characterized by an atypical inverted U-shaped curve with a breakpoint at approximately CMI = 2.08. Subgroup analysis revealed consistent findings across various demographic and clinical subpopulations. The findings of this study demonstrate a substantial correlation between elevated CMI levels and an increased incidence of SI within the US population. Early interventions targeted at individuals with elevated CMI levels, such as psychological support or lifestyle adjustments, may mitigate the risk of SI.

Abbreviations: BMI = body mass index, CMI = cardiometabolic index, HDL-C = high-density lipoprotein cholesterol, NCHS = National Center for Health Statistics, NHANES = National Health and Nutrition Examination Survey, PHQ-9 = Patient Health Questionnaire-9, SI = suicidal ideation, TG = triglycerides, WC = waist circumference, WHtR = waist-to-height ratio.

Keywords: cardiometabolic index, mental health, NHANES, suicidal ideation

1. Introduction

Every year, suicide claims the lives of 703,000 individuals globally, making it one of the most common causes of death. Given its severity, reducing suicide mortality rates has been prioritized as a global objective by the World Health Organization.[1] Suicidal behavior is defined as "thoughts and actions of individuals intentionally ending their own life," including suicidal ideation (SI), suicide attempts, and suicide fatalities, according to the Centers for Disease Control and Prevention (CDC) in the United States.[2] Studies have shown distinctive characteristics in the progression from SI to action (planning and attempts).[3] Research by Yen Sin Koh suggests that individuals with mood disorders are more likely to have suicide intentions, with rates of suicide planning and attempts at 17.7% and 10.6%, respectively. Additionally, over 80.0% of these events occur within a year of formulating suicidal plans.[4] Therefore, early identification and intervention of SI can effectively reduce the incidence of suicidal behavior.

In recent years, researchers have increasingly explored biological markers associated with suicide and found the

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

This study was reviewed and approved by the NCHS Ethics Review Board. The patients/participants provided written informed consent to participate in this study.

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significant impact of lipid metabolism on mental health advancement.[5] Low levels of HDL-C (high-density lipoprotein cholesterol) and elevated levels of triglycerides (TG) have been linked to depression.[6] Further investigations have revealed a significant correlation between lipid abnormalities, elevated triglyceride levels, and the severity of symptoms associated with depression, including SI, particularly among individuals with major depressive disorder.[7] Studies suggest that obesity and overweight are inversely associated with suicide mortality rates but positively correlated with SI.[8] These research findings emphasize the crucial role of lipid metabolism in the field of mental health, providing a theoretical foundation for exploring the relationship between lipid and obesity metabolism and SI.[9]

Currently, traditional indicators of lipid metabolism primarily include cholesterol, body mass index (BMI), TG, and waist-to-hip ratio.[10] The most recent research has introduced a novel indicator for evaluating visceral fat distribution and dysfunction: the cardiac metabolism index (CMI). This index is calculated by multiplying the TG/HDL-C by the waist-to-height ratio (WHtR).[11] Due to its comprehensive consideration of abdominal fat accumulation and lipid abnormalities, CMI has been validated as a robust and independent clinical discriminator for obesity, providing a more accurate reflection of metabolic function compared to traditional anthropometric measures.[12] Studies suggest that abdominal obesity is a contributing factor to depression, with research showing a positive correlation between CMI and depressive symptoms, especially among hypertensive patients.[13] As CMI has been shown to be an effective predictor of depression risk in individuals with lipid abnormalities,[14] investigating the relationship between CMI and mental health offers promising prospects.

While mounting evidence suggests a link between psychological variables and lipid metabolism, the connection between SI and CMI has not been extensively investigated in previous research. Therefore, we utilized data from the National Health and Nutrition Examination Survey (NHANES) of adult Americans to analyze the relationship between SI and CMI. The primary objective of this research is to investigate the potential predictive role of CMI regarding suicidal thoughts, aiming to elucidate the connection between lipid metabolism and mental well-being.

2. Materials and methods

2.1. Study population

The cross-sectional data utilized in this study was obtained from the NHANES, a program administered by the National Center for Health Statistics (NCHS) aimed at evaluating the nutritional and health status of the American population. The program received approval from the NCHS Ethics Review Board, and all participants provided informed consent. NHANES employs a sophisticated multistage, stratified, clustered probability sampling process to ensure a representative sample of the US population. Data, including demographic details, physical assessments, and laboratory tests were collected through in-home interviews and visits to a mobile examination center. The complete NHANES dataset is publicly accessible via the official webpage at https://www.cdc.gov/nchs/nhanes/.

Our analysis utilized NHANES data collected between 2005 and 2018, incorporating participants with complete datasets covering both SI and CMI. The study initially included a total of 70,190 participants. Subsequently, individuals under the age of eighteen (n = 28,047), pregnant individuals (n = 727), and those lacking sufficient information for SI (n = 5653) and CMI data (n = 19,904) were excluded. This resulted in a final analytic group comprising 15,849 participants (Fig. 1).

2.2. Definition of suicidal ideation

The Patient Health Questionnaire-9 (PHQ-9), a robust and reliable diagnostic instrument based on the DSM-V criteria and capable of yielding a maximum total score of 27, was utilized to evaluate SI.[15] In previous studies, individuals were categorized into 2 groups based on their PHQ-9 scores: <10, indicating the absence of depression, and ≥10, indicating the presence of depression.[16] This section of the questionnaire, particularly question 9, is specifically designed to detect signs of SI in primary care and health clinics.[17] The questionnaire assessed the frequency of thoughts related to self-harm or death over the past 2 weeks.[18] Scores ranging from 0 to 3 indicate varying degrees of ideation, with responses categorized as "None" or any level of frequency, offering insights into the presence of SI.[19]

2.3. Assessment of cardiometabolic index

Anthropometric and biochemical data, including height, waist circumference (WC) (cm), TG levels (mg/dL), and HDL-C levels (mg/dL), were utilized to mathematically calculate the CMI serving as the exposure variable.[20] The WHtR was determined by the ratio of WC to height (WHtR = WC/height), while CMI was computed as the ratio of TG to HDL-C multiplied by WHtR (CMI = T/HDL-C × WHtR).[21]

2.4. Covariables

Covariates, selected based on clinical plausibility and insights derived from prior research, were considered as potential factors influencing the relationship between SI and CMI. These covariates include gender, age (years), race, education level, marital status (widowed, divorced, separated, and never married/married or living with partner), BMI, WC (cm), poverty-to-income ratio (PIR), smoking status (smoker or nonsmoker), diabetes, hypertension, hyperlipidemia, coronary heart disease, stroke, depressive symptoms (without depression/with depression), HDL-C levels (mmol/L), weight (kg), total cholesterol levels (mg/dl), WHtR, and TG levels (mmol/L). BMI values were categorized into 3 groups: underweight (BMI < 25 kg/m^2), overweight (BMI 25–30 kg/m^2), and obese (BMI ≥ 30 kg/m^2).[22]

The PHQ-9 was utilized to assess depressive symptoms, with scores equal to or exceeding 10 indicating the presence of depression.[23] Comprehensive details regarding the quantitative procedures of study variables can be accessed by the public on the official website at www.cdc.gov/nchs/nhanes/.

2.5. Statistical analysis

Following CDC guidelines, all statistical analyses accounted for the complexities of multistage cluster surveys, adhering to NHANES analytical and reporting criteria, which involved detailed considerations of survey design complexities. For continuous variables, the standard deviation and mean were calculated, while categorical variables were expressed as percentages. Weighted Student *t* test was employed for continuous variables, and the weighted chi-square test was used for categorical variables to assess differences across cohorts categorized by the presence or absence of SI. Moreover, the relationship between CMI and the existence of SI was examined using multivariate logistic regression analysis in 3 separate models. Model 1 represented the unadjusted model, while Model 2 adjusted for age, race, and gender. Model 3 included adjustments for the following variables, such as age, gender, marital status, race, income-to-poverty ratio, smoking status, education level, diabetes, heart disease, stroke, and hypertension. Additionally, smooth curve

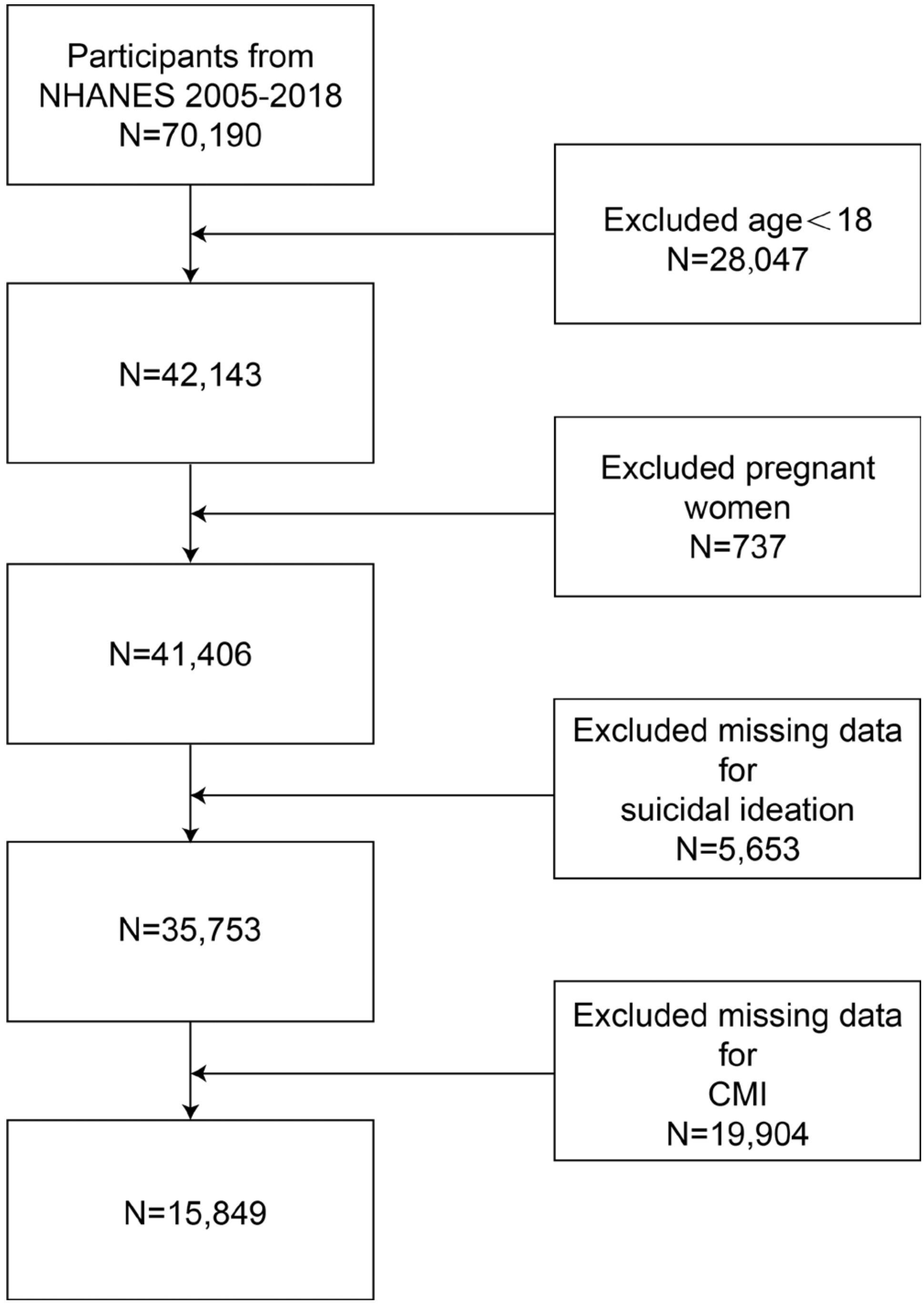

Figure 1. Flowchart of participant selection. NHANES = National Health and Nutrition Examination Survey.

fitting was conducted to investigate the nonlinear relationship between CMI levels and SI using the penalized spline approach and restricted cubic spline regression analysis. A two-piecewise linear regression model was employed for analyzing the possibility of threshold effects and enhancing the overall understanding of the shifting trends in the relationship between CMI and SI. The effectiveness of this relationship was examined across various demographic backgrounds through subgroup analysis and interaction testing, with factors such as age, gender, education level, race, marital status, diabetes, BMI, hypertension, hyperlipidemia, coronary heart disease, stroke, and smoking status defining the participants. A *P*-value of <.05 indicated significant discrepancies. All statistical analyses were conducted utilizing R program (http://www.r-project.org) and EmpowerStats (http://www.empowerstats.com).

3. Results

3.1. Baseline characteristics of participants

Following a thorough screening process, a total of 15,849 individuals were enrolled in our study and categorized into 2 groups based on the presence or absence of SI. Among those, 2978 individuals did not report SI, while 12,871 individuals did. Non-Hispanic Whites constituted the largest percentage of the sample (42.81%), with 49.45% of them being women and a mean age of 48.29 ± 18.58 years. The average percentage of SI cases in the study cohort was 3.47%, with an average CMI of 0.75 ± 1.09. Significant differences were observed between individuals with and without SI across all variables, except for weight, total cholesterol, age, and hyperlipidemia. Individuals experiencing SI were more likely to be female, of non-Hispanic White ethnicity, unmarried (including widowed, divorced, separated, or never married), have attained some college education or an Associate's degree, have a lower income, be smokers, and have obesity. They also tended to exhibit depressive symptoms, shorter height, and higher levels of WHtR, TG, and CMI. Conversely, they had a lower risk of diabetes, hypertension, coronary heart disease, and stroke, and lower levels of HDL-C (all *P*-values < .05) (details in Table 1).

3.2. The association between CMI and SI

Multivariate regression analysis revealed a significant association between SI and CMI levels, as depicted in Table 2, demonstrating a correlation between higher CMI levels and an increased probability of SI. For each unit increase in CMI, there was a seven-percentage point rise in the likelihood of SI, evident in both the partially adjusted model (OR = 1.07; 95% CI: 1.02–1.13; *P* = .0029) and the unadjusted model (OR = 1.07; 95% CI: 1.02, 1.12; *P* = .0065). However, the statistical analysis revealed that there was no significant connection between CMI and SI in model 3 (OR = 1.04; 95% CI: 0.98, 1.10; *P* = .2038), which encompasses all variables. To further investigate this association, sensitivity analysis was conducted using partially adjusted models, categorizing CMI levels into tertiles. Notably, Tertile 3 demonstrated a significant

Table 1

Characteristics of the study population.

Characteristic	Total (N = 15,849)	Without depression (N = 15,278)	With depression (N = 571)	*P*-value
Age (year)	48.29 ± 18.58	48.29 ± 18.60	48.36 ± 18.12	.923
Gender (%)				.015
Male	8011 (50.55%)	7751 (50.73%)	260 (45.53%)	
Female	7838 (49.45%)	7527 (49.27%)	311 (54.47%)	
Race (%)				<.001
Mexican American	2571 (16.22%)	2472 (16.18%)	99 (17.34%)	
Other Hispanic	1572 (9.92%)	1474 (9.65%)	98 (17.16%)	
Non-Hispanic White	6785 (42.81%)	6552 (42.89%)	233 (40.81%)	
Non-Hispanic Black	3276 (20.67%)	3180 (20.81%)	96 (16.81%)	
Other Race	1645 (10.38%)	1600 (10.47%)	45 (7.88%)	
Marital status (%)				<.001
Married or living with partner	9035 (59.59%)	8780 (60.08%)	255 (46.70%)	
Widowed, divorced, separated, and never married	6126 (40.41%)	5835 (39.92%)	291 (53.30%)	
Education level (%)				<.001
<9th Grade	1504 (10.08%)	1419 (9.86%)	85 (15.92%)	
9–11th Grade	2153 (14.42%)	2040 (14.19%)	110 (20.60%)	
High school Grad/GED or equivalent	3434 (23.00%)	3306 (22.97%)	128 (23.97%)	
Some college or AA degree	4357 (29.19%)	4208 (29.23%)	149 (27.90%)	
College graduate or above	3480 (23.31%)	3418 (23.75%)	62 (11.61%)	
Body mass index (kg/m^2), (%)				<.001
<25	4815 (30.42%)	4662 (30.55%)	153 (26.89%)	
25 to <30	5190 (32.79%)	5025 (32.93%)	165 (29.00%)	
≥30	5825 (36.80%)	5574 (36.52%)	251 (44.11%)	
Waist circumference (cm)	98.75 ± 16.57	98.66 ± 16.53	101.24 ± 17.53	<.001
Income to poverty ratio	2.50 ± 1.62	2.53 ± 1.62	1.84 ± 1.43	<.001
Smoking status (%)				<.001
Yes	6887 (45.17%)	6569 (44.69%)	318 (57.92%)	
No	8361 (54.83%)	8130 (55.31%)	231 (42.08%)	
Diabetes (%)				<.001
Yes	1973 (12.46%)	1872 (12.26%)	101 (17.69%)	
No	13,495 (85.22%)	13,039 (85.42%)	456 (79.86%)	
Borderline	368 (2.32%)	354 (2.32%)	14 (2.45%)	
Hypertension (%)				<.001
Yes	5569 (35.19%)	5318 (34.86%)	251 (43.96%)	
No	10,258 (64.81%)	9938 (65.14%)	320 (56.04%)	
Hyperlipidemia (%)				.145
Yes	8277 (69.94%)	8009 (70.06%)	268 (66.67%)	
No	3557 (30.06%)	3423 (29.94%)	134 (33.33%)	
Coronary heart disease (%)				<.001
Yes	620 (4.17%)	576 (4.02%)	44 (8.26%)	
No	14,259 (95.83%)	13,770 (95.98%)	489 (91.74%)	
Stroke (%)				<.001
Yes	550 (3.69%)	511 (3.55%)	39 (7.34%)	
No	14,373 (96.31%)	13,881 (96.45%)	492 (92.66%)	
Depressive symptom (%)				<.001
Without depression	14,300 (90.23%)	14,114 (92.38%)	186 (32.57%)	
With depression	1549 (9.77%)	1163 (7.62%)	385 (67.43%)	
Weight (kg)	81.51 ± 21.22	81.46 ± 21.19	82.68 ± 21.97	.193
Height (cm)	167.63 ± 10.05	167.67 ± 10.05	166.35 ± 10.03	.002
TC (mg/dL)	190.62 ± 41.75	190.54 ± 41.62	192.54 ± 45.04	.584
HDL-C (mmol/L)	1.39 ± 0.41	1.39 ± 0.41	1.33 ± 0.39	<.001
WHtR	0.59 ± 0.10	0.59 ± 0.10	0.61 ± 0.11	<.001
TG (mmol/L)	1.41 ± 1.25	1.41 ± 1.25	1.58 ± 1.27	<.001
CMI	0.75 ± 1.09	0.75 ± 1.09	0.89 ± 1.10	<.001

HDL-C = high-density lipoprotein cholesterol, TC = total cholesterol.

61% higher likelihood of SI compared to Tertile 1, characterized by the lowest CMI (OR = 1.61; 95% CI: 1.31, 1.98; p for trend < 0.0001). However, after comprehensive adjustments, the observed correlation (OR = 0.88; 95% CI: 0.95, 1.52; *P* = .1333) did not reach statistical significance. Furthermore, there was no significant distinction between tertile 1 and tertile 2 in any of the 3 models (Table 2).

3.3. A nonlinear relationship between CMI and SI

We conducted a comprehensive analysis utilizing advanced statistical techniques. Smooth curve fits and weighted generalized additive models were used to properly evaluate the nonlinear relationship between CMI levels and the incidence of SI. Our investigation demonstrated a clear nonlinear correlation between the level of CMI and the incidence of SI (Fig. 2). A two-segment linear regression model was applied, and the results demonstrated that the relationship between CMI and SI followed an atypical inverted U-shaped curve. Notably, a breakpoint at 2.08 was identified, determined by a logarithmic likelihood ratio test with a *P*-value of .007 (Table 3).

3.4. Subgroup analysis

This subgroup analysis aimed to examine how the relationship between SI and CMI levels may vary across different demographic or clinical subpopulations, thereby providing insights into potential effect modifiers or stratification factors. In order to evaluate the consistency of the relationship between CMI levels and SI across various demographic settings, interaction tests, and subgroup analysis were conducted, stratified by age (<50, ≥50), gender, race, BMI (<25, 25–30, >30), education level, marital status, hypertension, hyperlipidemia, diabetes, coronary heart disease, stroke, and smoking status. In the age-stratified analysis, for individuals <50 years old, the relationship between CMI and SI was characterized by an odds ratio (OR = 1.03; 95% CI: 0.95, 1.12; p for interaction = 0.9229), while for those ≥50 years old, the OR was 1.04 (95% CI: 0.95, 1.13; p for interaction = 0.9229). Among males, the OR was 1.07 (95% CI: 0.99, 1.15; p for interaction = 0.3433), and among females, it was 1.01 (95% CI: 0.90, 1.12; p for interaction = 0.3433). In the Mexican American subgroup, the OR was 1.06 (95% CI: 0.88, 1.28; p for interaction = 0.4359), for Other Hispanic was 1.10 (95% CI: 0.99, 1.21; p for interaction = 0.4359), Non-Hispanic White (N = 6208) had an OR of 0.99 (95% CI: 0.89, 1.09; p for interaction = 0.4359), Non-Hispanic Black had an OR of 1.13 (95% CI: 0.88, 1.45; p for interaction = 0.4359), and Other Race had an OR of 1.08 (95% CI: 0.71, 1.63; p for interaction = 0.4359). This was the only factor with a significant *P*-value for interaction (*P* = .0269). For those with <9th-grade education, the OR was 1.12 (95% CI: 1.01, 1.24; p for interaction = 0.0269), and for college graduates or above, the OR was 1.26 (95% CI: 1.05, 1.52; p for interaction = 0.0269). In contrast, those with 9 to 11th-grade education (N = 1937) had an OR of 0.96 (95% CI: 0.77, 1.18; p for interaction = 0.0269), and those with some college or an AA degree had an OR of 0.89 (95% CI: 0.71, 1.11; p for interaction = 0.0269). This indicates that the relationship between CMI and SI varies significantly across different education levels, with higher education levels showing a stronger positive association in some cases.

Table 2

The association between CMI and suicidal ideation.

	Crude model (Model 1)	Partially adjusted model (Model 2)	Fully adjusted model (Model 3)
	OR (95% CI) *P*-value	OR (95% CI) *P*-value	OR (95% CI) *P*-value
CMI	1.07 (1.02, 1.13) .0029	1.07 (1.02, 1.12) .0065	1.04 (0.98, 1.10) .2038
CMI tertiles			
Tertile 1	Reference	Reference	Reference
Tertile 2	1.08 (0.87, 1.35) .4984	1.08 (0.86, 1.35) .5252	0.88 (0.68, 1.12) .2999
Tertile 3	1.61 (1.31, 1.98) < .0001	1.61 (1.30, 2.00) < .0001	1.20 (0.95, 1.52) .1333
P for trend	1.73 (1.40, 2.15) < .0001	1.74 (1.39, 2.18) < .0001	1.32 (1.03, 1.70) .0281

Model 1, no covariates were adjusted. Model 2, age, gender, and race were adjusted. Model 3, age, gender, race, marital status, education level, income-to-poverty ratio, smoking status, diabetes, coronary heart disease, stroke, TC and hypertension were adjusted.
95% CI = 95% confidence interval; OR = odds ratio.

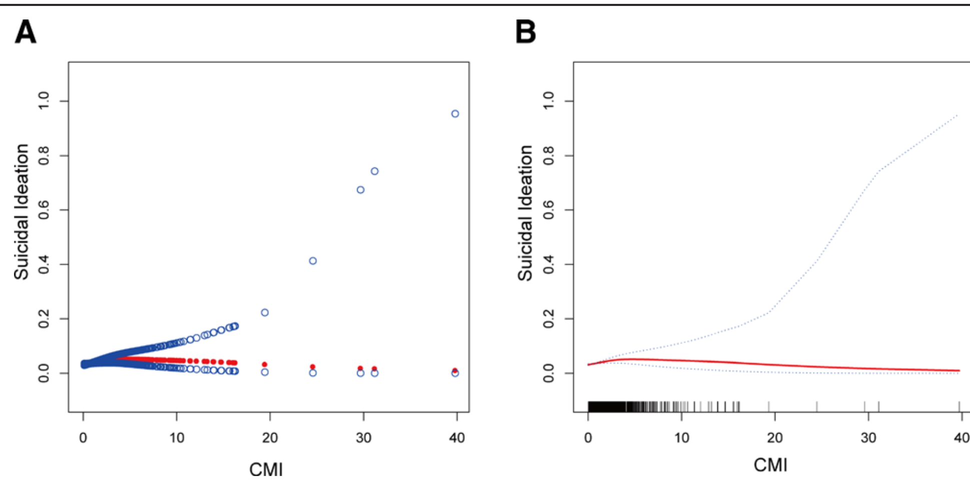

Figure 2. The association between cardiometabolic index and suicidal ideation. (A) The solid red line represents the smooth curve fit between variables. (B) Blue bands represent the 95% confidence interval from the fit.

Table 3

The threshold effect of CMI on suicidal ideation was analyzed using a two-part linear regression model.

Suicidal ideation	Model: saturation effect analysis
Fitting by the standard linear model	
OR (95% CI)	1.04 (0.98, 1.10)
P-value	.2038
Fitting by two-piecewise linear model	
Breakpoint (K)	2.08
OR1 (<K)	1.31 (1.10, 1.57) .0027
OR2 (>K)	0.96 (0.85, 1.08) .4781
Logarithmic likelihood ratio test *P*-value	.007

Model 1, no covariates were adjusted. Model 2, age, gender, and race were adjusted. Model 3, age, gender, race, marital status, education level, income-to-poverty ratio, smoking status, diabetes, coronary heart disease, stroke, and hypertension were adjusted.
95% CI = 95% confidence interval; OR = odds ratio.

Overall, the p-values for interaction suggest that, except for the education subgroup, there are no statistically significant differences in the CMI–SI relationship across various demographic contexts, indicating the robustness of the association across most subpopulations (Table 4).

4. Discussion

Utilizing data from the NHANES database, covering the years 2005 to 2016, representative of the US population, this study aimed to investigate the correlation between CMI levels and the occurrence of SI. The research revealed a statistically significant link between CMI and SI, suggesting those with higher CMI values were more likely to experience SI. Observations of nonlinear positive associations were noteworthy, evidenced by varying correlations found on both sides of the breakpoint at CMI = 2.08. Furthermore, subgroup analysis and interaction testing revealed that the relationship between CMI and SI remained consistent across various demographic scenarios and population settings. Our findings suggest an association between CMI levels and SI risk in the US population. Individuals with elevated CMI levels may necessitate tailored interventions to mitigate SI risk, highlighting the clinical utility of CMI as a biomarker for mental health assessment and early intervention strategies.

The ongoing investigation into the clinical utility of CMI is crucial for advancing our research. Computed by multiplying the WHtR by the TG/HDL-C ratio, CMI integrates lipid and obesity parameters into a simple and reproducible indicator.[24] These measurements are routinely included in health assessments and are easily interpretable.[25] As an innovative marker of visceral fat distribution and dysfunction, CMI is believed to predict various metabolic conditions, including diabetes, stroke, kidney disease, fatty liver, and hypertension.[26–30] A recent cross-sectional study conducted by Xiang Zhou and colleagues, utilizing data from NHANES, examined a sample of 3794 individuals, revealing a correlation between elevated CMI and an increased likelihood of suffering depression. This recent finding not only redirects our research focus but also highlights the potential of CMI as an indicator of mental health. Our study contributes to this field by uncovering a significant correlation between CMI levels and SI among the US population. These findings underscore the importance of incorporating CMI into mental health evaluations and early intervention strategies, especially for individuals with elevated CMI levels who may be at risk of SI.

To our knowledge, this research represents the first attempt to analyze the correlation between CMI and SI. As a novel measure indicating the accumulation of abdominal fat and lipid irregularities, CMI provides a broader scope of data to assess individual metabolic function and obesity status.[31]

Despite extensive investigations into the link between obesity and SI in previous studies, the exploration of the relationship between CMI and SI remains limited in current research. For example, a cross-sectional research conducted by Amber A. Mather and colleagues enrolled 36,984 Canadians aged 15 years and older, using a BMI greater than or equal to 30 as an indicator of obesity. Their findings revealed a correlation between obesity and psychiatric disorders, as well as suicidal attempts, within the Canadian population.[32] Similarly, Gareth R. Dutton et al found a significant correlation between higher levels of obesity and an increased risk of SI, along with a greater psychological burden, in a cross-sectional study involving 271 participants.[33] Another cross-sectional investigation led by Gianluca Rosso and the team recruited 847 patients diagnosed with bipolar disorder, using BMI and WC as metrics for assessing obesity. The study suggested a potential correlation between obesity and the preference for violent suicide attempts.[34] Additionally, Birgit Wagner and her colleagues conducted research in 2011 to determine the incidence of suicide attempts and suicidal behavior across various BMI categories, using a representative sample of 2436 German citizens. Their study indicated that individuals who were severely obese were more likely to engage in suicidal behavior.[35] While prior studies have extensively explored the association between obesity and SI, this study represents a pioneering effort to examine the specific relationship between CMI and SI, which remains relatively unexplored. Our research closes this knowledge gap and aligns with the majority of previous research, indicating that CMI, serving as a trustworthy marker of visceral obesity, exhibits a favorable correlation with an increased likelihood of SI. Furthermore, investigating the possible mechanisms by which abdominal fat accumulation and lipid irregularities, as reflected by CMI, may impact the onset of SI holds significant clinical importance. Such exploration could offer valuable insights into identifying new therapeutic strategies for preventing suicidal behavior among individuals with elevated CMI levels.

The current study indicates that the specific mechanisms linking CMI and SI are still not fully understood. However, we may begin to investigate the same processes that explain the relationship between obesity and SI. These mechanisms likely involve complex interactions between biological, psychological, and social factors. From a psychological perspective, the association between obesity and SI can be explained by weight stigma. Weight stigma, rooted in misconceptions about laziness and lack of self-discipline, subjects individuals with overweight or obese to discrimination across various domains, including the workplace, education, healthcare, and society as a whole.[36] Studies have shown that obese individuals facing heightened weight stigma experience increased depressive symptoms, reduced self-esteem, and elevated suicidality.[37–39] This underscores the detrimental impact of societal attitudes towards obesity on mental health and suicidal thoughts.[40] There might also be a biological component to the correlation between fat and SI. The serotonin hypothesis, a well-established theory in the field, suggests that decreased central serotonin levels are associated with heightened suicidal tendencies, aggressive impulses, and increased behavioral risks.[41] Animal studies have demonstrated that obesity induced by a high-fat diet leads to diminished serotonin release and neuron activity in the hypothalamus. Postmortem analysis of hypothalamic tissue from overweight individuals has revealed decreased levels of the serotonin transporter protein responsible for serotonin uptake.[42,43] Furthermore, obese females have been found to exhibit lower levels of serotonin and its metabolites in cerebrospinal fluid compared to their lean counterparts.[44] These findings support the notion that reduced serotonin levels in obesity may contribute to an increased risk of SI or behavior. Moreover, chronic inflammation, frequently associated with abdominal obesity and elevated blood lipids, has been implicated in higher rates of suicide.[45] Research indicates that individuals with metabolic

Table 4

Association between CMI and suicidal ideation in subgroups.

Subgroup		OR (95%CI)	*P* for interaction
Age (year)			.9229
<50	N = 6758	1.03 (0.95, 1.12)	
≥50	N = 6941	1.04 (0.95, 1.13)	
Gender			.3433
Male	N = 6901	1.07 (0.99, 1.15)	
Female	N = 6798	1.01 (0.90, 1.12)	
Race			.4359
Mexican American	N = 2076	1.06 (0.88, 1.28)	
Other Hispanic	N = 1272	1.10 (0.99, 1.21)	
Non-Hispanic White	N = 6208	0.99 (0.89, 1.09)	
Non-Hispanic Black	N = 2731	1.13 (0.88, 1.45)	
Other race	N = 1412	1.08 (0.71, 1.63)	
BMI (kg/m^2)			.6880
<25	N = 3971	1.22 (0.85, 1.77)	
25–30	N = 4554	1.03 (0.91, 1.17)	
>30	N = 5158	1.03 (0.95, 1.11)	
Education level			.0269
<9th grade	N = 1276	1.12 (1.01, 1.24)	
9–11th grade	N = 1937	0.96 (0.77, 1.18)	
High school grad/GED or equivalent	N = 3157	1.00 (0.85, 1.18)	
Some college or AA degree	N = 4061	0.89 (0.71, 1.11)	
College graduate or above	N = 3261	1.26 (1.05, 1.52)	
Marital status			.2432
Married/living with partner	N = 8281	1.07 (1.00, 1.14)	
Widowed/divorced/separated/never married	N = 5417	0.99 (0.87, 1.12)	
Hypertension			.7736
Yes	N = 5050	1.03 (0.95, 1.12)	
No	N = 8629	1.05 (0.96, 1.14)	
Hyperlipidemia			.5831
Yes	N = 7543	1.03 (0.94, 1.12)	
No	N = 3080	1.08 (0.92, 1.26)	
Diabetes			.0833
Yes	N = 1777	1.03 (0.95, 1.13)	
No	N = 11581	1.06 (0.97, 1.15)	
Borderline	N = 333	0.47 (0.18, 1.22)	
Coronary heart disease			.9501
Yes	N = 570	1.03 (0.74, 1.43)	
No	N = 13081	1.04 (0.98, 1.10)	
Stroke			.5393
Yes	N = 513	0.96 (0.74, 1.24)	
No	N = 13175	1.04 (0.98, 1.10)	
Smoking status			.7392
Yes	N = 6317	1.05 (0.96, 1.14)	
No	N = 7372	1.03 (0.94, 1.12)	

The results show that the subgroup analysis was adjusted for all presented covariates except the effect modifier.
95% CI = 95% confidence interval; OR = odds ratio.

syndrome and elevated serum inflammatory markers are at increased risk of suicide attempts, indicating a potential role of inflammation in precipitating suicidal behavior among individuals with obesity.[46] Therefore, utilizing the CMI as a tool for evaluating metabolic dysfunction and visceral obesity could offer valuable insights into the mechanisms associated with SI. This comprehensive approach aids in the identification and management of mental health risks among individuals grappling with obesity.

In an attempt to further understand the underlying mechanisms of the observed inverted U-shaped curve between CMI and SI, we propose several hypotheses. On the biological front, it is possible that at lower CMI levels, the body's compensatory mechanisms are sufficient to maintain normal physiological and psychological functions. As CMI increases, the cumulative effects of metabolic dysregulation,[47] such as elevated inflammation, oxidative stress, and disrupted neurotransmitter systems, may gradually emerge. However, at extremely high CMI levels, other physiological changes might occur. The body may adapt in different ways, such as activating certain stress-resistant pathways,[48] which could potentially lead to a decrease in the SI risk, resulting in the downward part of the atypical inverted U-shaped curve. From a psychosocial perspective, at moderate CMI levels, individuals may start to experience the negative impacts of their deteriorating physical health on their self-esteem, social relationships,[49] and quality of life. This could lead to increased psychological distress and SI. However, as the condition becomes more severe, social support systems may be mobilized more effectively, and individuals may also become more aware of their health issues and seek professional help,[50] which could potentially mitigate the risk of SI, contributing to the observed curve pattern. Future research should focus on validating these hypotheses through longitudinal studies and in-depth mechanistic investigations.

Our study offers several significant benefits. Initially, by utilizing NHANES data, a nationally representative sample of substantial size, and meticulously controlling for confounding covariates, we have enhanced the validity and reliability of our findings. Additionally, as the first investigation to explore the relationship between CMI and the likelihood of suicidal thoughts, our research offers insights into a demographically diverse cohort of adult individuals in the United States. Furthermore, the study's robust methodology, including subgroup analysis, adjustment for relevant factors, and detailed exploration of nonlinearity and threshold effects, provides a comprehensive understanding of the link between SI and CMI. However, our study also has several inherent limitations. Firstly, the observational nature of our study limits our ability to infer causation, leading to uncertainty regarding the directionality of associations and introducing the potential for reverse causality. Secondly, while the PHQ-9 is commonly employed to assess SI, its broader scope may encompass non-suicidal self-harm, potentially impacting the evaluation of its relationship with SI. Thirdly, reliance on personal interviews for assessing SI introduces inevitable recall bias. Fourthly, while the PHQ-9 questionnaire may not comprehensively evaluate SI risk, its ninth item has demonstrated efficacy as an indicator of SI, emphasizing its utility in clinical practice for screening, diagnosing, and managing SI.[51] Fifthly, despite our efforts in adjusting for confounding factors such as age, gender, socioeconomic status, and preexisting medical conditions, potential residual confounding remains a concern. There might be unmeasured or difficult-to-measure variables, like genetic susceptibility to both cardiometabolic disorders and mental health issues, or long-term exposure to environmental stressors that could influence both CMI and SI. These unaccounted factors could potentially distort the true relationship between the 2 variables under study. Lastly, the reliance on self-reported SI data poses a significant challenge. Participants may be influenced by social desirability bias, causing them to either downplay or overstate their experiences of SI. This could lead to misclassification of SI status and inaccurate estimates of the association with CMI.

5. Conclusion

Our study identified a significant independent link between elevated CMI levels and an increased incidence of SI, highlighting the potential of CMI as a biomarker for identifying individuals at risk of suicidal thoughts. Once elevated CMI levels are detected, healthcare providers can take targeted actions, like psychological therapies such as cognitive-behavioral therapy and interpersonal therapy can be implemented for early intervention. In terms of lifestyle, personalized exercise plans such as brisk walking and dietary changes like reducing high-fat/sugar intake and increasing the consumption of fruits and vegetables can be recommended, all aiming to mitigate the risk of suicidal thoughts and behaviors.

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