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The interplay between depressive symptoms, body mass index change patterns in adulthood, and all-cause mortality risk: a population-based study

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Abstract

Background Recent studies have suggested body mass index (BMI) change patterns in adulthood may be crucial for depression. This purpose of this study is to evaluate the impact of adult BMI change patterns on depression.

Methods The National Health and Nutrition Examination Survey 2007 to 2018 generated the data. The relationships between adult BMI change patterns and depression / Patient Health Questionnaire 9 (PHQ-9) were investigated using logistic regression and generalized linear model with a Poisson distribution. The relationships between BMI change patterns, depressive symptoms, and all-cause mortality were examined by Cox proportional hazards models. Kaplan-Meier curves were employed to illustrate the cumulative incidence over time. To explore whether adult BMI change patterns mediate this link between depression and all-cause mortality, mediation analysis was conducted.

Results A total of 10,448 participants were included, with 7.8% reporting depression. Significant differences were observed in demographic, lifestyle, and health characteristics across BMI change patterns. The high-increase pattern was linked to a1.61 times greater odds of depression after adjustment (odds ratio = 1.61, 95% confidence interval (CI): [1.16, 2.24], $P = 0.006$) compared to the non-overweight pattern. Gender and age differences were also observed. The higher PHQ-9 was correlated with increased all-cause mortality risk, even after adjustment (hazard ratio: 1.03; 95%CI: 1.02–1.05). Mediation analysis revealed that adult BMI change patterns mediated 26.98% of the correlation between depressive symptoms and all-cause mortality.

Conclusion Persistent obesity in adulthood rises the risk of depression, and BMI change patterns playing a modest role in mediating the link between depressive symptoms and all-cause mortality. Early intervention in individuals at-risk BMI change patterns might reduce depression risk. Future research should investigate whether modifying BMI change patterns can lower depression incidence.

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Clinical trial number Not applicable.

Keywords Body mass index change patterns, Depression, Mortality, Mediation

Introduction

One of the most prevalent mental disease in the world and a significant contributor to the global burden of illnesses is depression [1]. And it has been consistently linked to increased risks of all-cause and cardiovascular disease mortality [2, 3]. Despite robust evidence supporting this association, the underlying mechanisms, particularly the role of mediators and confounders, remain poorly understood [2].

Previous studies have explored the link between depression and mortality in both general populations and specific patient groups. For instance, depression was related to a 52% increased risk of all-cause mortality [4]. But the robustness of these findings have called into question, due to methodological limitations (inadequate control for confounders like comorbid mental disorders and health behaviors, small sample sizes, and short follow-up periods [5]. A subsequent meta-analysis in 2017, encompassing over 3.6 million participants, highlighted similar limitations, underscoring the need for rigorous research to disentangle causal pathways and address potential biases [5].

While substantial research has focused on the bidirectional association between depression and physical health, less attention has been given to dynamic factors like body mass index (BMI) change patterns in shaping mental health outcomes. Studies on weight change and mental health have employed cross-sectional designs or evaluated weight at two discrete time points, failing to capture the complex longitudinal patterns of BMI changes. Recent advancements in obesity research have shifted attention towards BMI change patterns—patterns of weight change over time—that provide a more nuanced understanding of the cumulative effects of weight on health outcomes [6]. And such approaches have yielded valuable insights into chronic disease including asthma and cardiovascular disease [7, 8].

Due to the dynamic nature of weight, a life-course perspective is crucial to capture the full impact of weight changes on depression. Identifying critical periods where interventions could reduce the risk of depression is essential. Only three studies have explored BMI trajectories over the life course in relation to adult depression [9–11]. Two of these studies [9, 11] relied on recalled body shape from non-representative samples, while the third [10] modeled BMI trajectories only up to age 24. These gaps underscore the need for population-based, longitudinal research that extends BMI change patterns into adulthood and examines their associations with depression.

Understanding how BMI change patterns relate to depression across adulthood is essential for identifying vulnerable subgroups and informing targeted interventions. This study sought to evaluate the correlation between distinct BMI change patterns during adulthood and depression risk among U.S. adults. By integrating longitudinal BMI data with comprehensive mental health assessments, this research seeks to improve our knowledge of the interplay between obesity and depression.

Materials and methods

Study sample

The National Health and Nutrition Examination Survey (NHANES) is a cross-sectional study designed to collect data from a nationally representative sample of the non-institutionalized, civilian population in the US. NHANES operates on a 2-year reporting cycle. Data collection involves a two-stage process: an in-home interview to gather information on demographics, socioeconomic status, and medical conditions, followed by a physical examination at a Mobile Examination Center (MEC), where clinical and laboratory tests are conducted.

For this study, data from the 2007–2008 through 2017–2018 cycles were incorporated, resulting in a sample of 10,448 adults. The dataset included clinical and laboratory results, and health-related questionnaires. The study protocol was approved by the National Center for Health Statistics Research Ethics Review Board, and all participants provided written informed consent. More information on NHANES procedures is available on their official website. A flowchart outlining the participant selection procedure was presented in Fig. 1.

Measurement of body mass index change patterns

Weight and height measurements were taken during the MEC examinations using calibrated equipment, and participants were asked to recall their weight at age 25. BMI at age 25 was self-reported by participants, whereas current BMI and the Patient Health Questionnaire-9 (PHQ-9) were assessed during the same NHANES examination visit. BMI [weight (kg) divided by height squared (m^2)] categorized based on World Health Organization (WHO) criteria [12]: underweight (< 18.5), normal weight (18.5–24.9), overweight (25.0-29.9), and obese (≥ 30.0).

As NHANES is a series of cross-sectional surveys, longitudinal BMI data were not available. Instead, we constructed BMI change patterns using BMI values at two time points: recalled BMI at age 25 and measured BMI at the time of the survey. This method has been used in

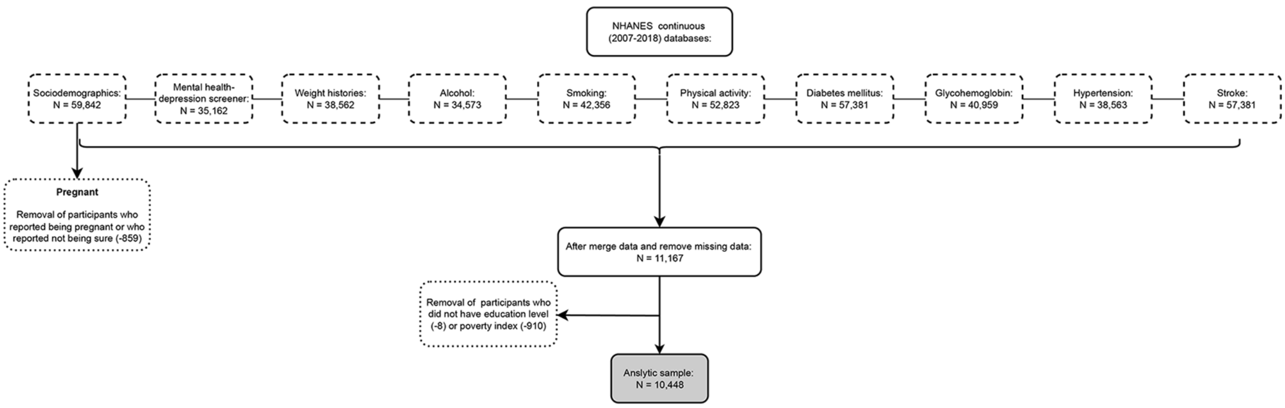

Fig. 1 Flow chart of participant selection

previous studies to estimate life-course weight change patterns when longitudinal data are not available [13, 14].

Participants were classified into four BMI change pattern groups based on their BMI at age 25 and at the time of the survey:

1. Non-overweight stable pattern: Participants who were either underweight at 25 but transitioned to normal weight or maintained normal weight across assessments.
2. Moderate increase pattern: Participants who had normal weight at 25 who progressed to overweight.
3. High increase pattern: Participants who were overweight participants at 25 and transitioned to obesity or remained obese.
4. Mixed pattern: Participants with fluctuating BMI over time.

Measurement of depressive symptoms

The PHQ-9, a validated tool that quantifies the severity and frequency of depressive symptoms experienced over the past two weeks, was adopted to measure depressive symptoms [15].

Measurement of mortality

All-cause mortality data were collected by linking NHANES records with the National Death Index (NDI). For participants who were still alive, survival time was calculated from the date of their NHANES examination to either their date of death or the end of the follow-up period (December 31, 2019).

Measurement of covariates

Covariates included demographic, socioeconomic, and health-related variables. Data on race/ethnicity, education, income (poverty-to-income ratio), smoking history, alcohol use, physical activity, and medical conditions (diabetes, hypertension, stroke) were collected through questionnaires [13, 16, 17]. Further details on data collection procedures are available in the NHANES Procedure Manual.

Statistical analysis

Due to the large sample size, participant characteristics were outlined by weighted means and standard deviations (SD) range for continuous variables or proportions for categorical variables. Survey-weighted linear regression models and Rau-Scott chi-squared test were implemented to compare differences across groups.

Post-hoc pairwise comparisons for selected continuous variables were performed using estimated marginal means with Tukey-adjusted *P*-values, accounting for the NHANES complex sampling design.

Weight logistic regression analyses were conducted to examine the correlation between BMI change patterns with depression. And generalized linear model (GLM) with a Poisson distribution and a log link function to model the PHQ-9 scores. Multiple model was adjusted for age, gender, ethnicity, education level, poverty index (<1.25, 1.25–3.49, ≥ 3.50), smoking status (current, former, never, <100 cigarettes in life), alcohol consumption (yes or no), physical activity (meet the physical activity guidelines or not), diabetes, hypertension and stroke. Subgroup analyses were examined according to gender and age (50–60, 60–70 and 70–80 years).

Cox proportional hazards models were conducted to evaluate links between BMI change patterns, depression, and all-cause mortality. Model assumptions were verified using Kaplan-Meier (KM) survival curves. The cumulative incidence of depressive symptoms over time was also assessed by BMI change patterns.

To account for NHANES' complex sampling design, all analyses applied survey weights. Statistical significance was set at a two-sided $P<0.05$, and analyses were executed using R version 4.3.0.

Results

Demographic characteristics of the study population

Among 10,448 individuals, the weighted mean PHQ-9 score was 2.97 (SD = 4.10), and the mean age was 62.96 (SD = 9.17) years. A total of 52.3% (n = 5195) of participants were female (Table 1). Participants in the high increase BMI change pattern group exhibited higher PHQ-9 scores compared to those in the non-overweight group. Post-hoc pairwise comparisons for PHQ-9 scores were presented in Figure S1. Significant differences were noticed across BMI change pattern groups in terms of age, gender, race/ethnicity, education, poverty index, alcohol consumption, smoking, physical activity, diabetes status, and hypertension status ($P < 0.05$). But no significant difference was observed in stroke status among the groups.

The association between BMI change pattern groups and depressive symptoms

Table 2 showed that when depressive symptoms were modeled as a categorical variable, individuals in the high increase pattern had a 1.61 times greater odds of reporting depression (odds ratio (OR) = 1.61, 95% confidence interval (CI): [1.16, 2.24], $P = 0.006$) compared to those in the non-overweight pattern. Additionally, the high increase pattern was associated with 0.34-point

Table 1 Characteristics of study sample (NHANES 2007–2018)

	All	Non-overweight	Moderate increase	High increase	Mixed	*P*
	***N* = 10,448**	***N* = 2526**	***N* = 2746**	***N* = 3688**	***N* = 1488**	
Gender						< 0.001
Male	5253 (47.7%)	1139 (38.4%)	1436 (49.0%)	1689 (46.2%)	989 (66.1%)	
Female	5195 (52.3%)	1387 (61.6%)	1310 (51.0%)	1999 (53.9%)	499 (33.9%)	
Age	62.96 (9.17)	63.82 (9.62)	63.78 (9.30)	61.79 (8.44)	62.78 (9.51)	<0.001
Race/ethnicity						0.003
Mexican American	2656 (15.3%)	555 (13.4%)	690 (15.3%)	994 (16.1%)	417 (16.6%)	
Other Hispanic	5280 (61.2%)	1399 (65.8%)	1412 (61.5%)	1768 (58.2%)	701 (59.7%)	
Non-Hispanic White	2512 (23.5%)	572 (20.8%)	644 (23.1%)	926 (25.6%)	370 (23.8%)	
Non-Hispanic Black						< 0.001
Other Race - Including Multi-Racial	1212 (4.1%)	156 (2.1%)	348 (4.3%)	522 (5.2%)	186 (4.3%)	
Education level	1005 (3.2%)	214 (2.7%)	292 (3.6%)	371 (3.4%)	128 (3.0%)	
< High school	5182 (78.3%)	1363 (80.9%)	1394 (79.0%)	1682 (76.0%)	743 (77.9%)	
> High school	2252 (9.2%)	430 (6.7%)	520 (8.2%)	989 (12.1%)	313 (8.6%)	
High school/general educational development	797 (5.2%)	363 (7.6%)	192 (4.9%)	124 (3.3%)	118 (6.1%)	
Poverty index						0.021
Extremely poor	2719 (15.3%)	621 (14.0%)	641 (13.9%)	1009 (16.5%)	448 (17.4%)	
Rich	3450 (48.2%)	908 (51.1%)	931 (48.9%)	1156 (46.0%)	455 (47.0%)	
Wealthy	4279 (36.5%)	997 (34.9%)	1174 (37.3%)	1523 (37.5%)	585 (35.6%)	
Alcohol consumption						0.001
Yes	7245 (75.2%)	1738 (75.7%)	1957 (77.4%)	2472 (72.3%)	1078 (77.5%)	
No	3203 (24.8%)	788 (24.3%)	789 (22.6%)	1216 (27.7%)	410 (22.5%)	
Smoking						< 0.001
< 100 cigarettes in life	5012 (48.8%)	1247 (49.9%)	1321 (48.7%)	1774 (48.1%)	670 (48.6%)	
Current smokers	1762 (15.9%)	507 (19.6%)	420 (14.4%)	496 (12.4%)	339 (20.2%)	
Former smokers	3674 (35.4%)	772 (30.5%)	1005 (36.8%)	1418 (39.5%)	479 (31.3%)	
Physical activity						< 0.001
Active	2465 (27.6%)	730 (35.2%)	684 (28.6%)	664 (19.9%)	387 (31.3%)	
Inactive	7983 (72.4%)	1796 (64.8%)	2062 (71.4%)	3024 (80.1%)	1101 (68.7%)	
Diabetes						< 0.001
Yes	7770 (79.9%)	2220 (92.1%)	2183 (85.8%)	2249 (66.5%)	1118 (80.1%)	
No	2678 (20.1%)	306 (7.9%)	563 (14.2%)	1439 (33.5%)	370 (19.9%)	
Hypertension						< 0.001
Yes	5833 (51.0%)	1083 (36.7%)	1489 (49.3%)	2471 (63.8%)	790 (48.6%)	
No	4615 (49.0%)	1443 (63.3%)	1257 (50.7%)	1217 (36.2%)	698 (51.4%)	
Stroke						0.298
Yes	680 (5.1%)	155 (4.9%)	160 (4.5%)	244 (5.2%)	121 (6.2%)	
No	9768 (94.9%)	2371 (95.1%)	2586 (95.5%)	3444 (94.8%)	1367 (93.8%)	
PHQ-9	2.97 (4.10)	2.54 (3.68)	2.65 (3.80)	3.56 (4.50)	2.88 (4.16)	< 0.001

Table 2 Multivariable logistic regression analysis examining the association between BMI change pattern groups and depressive symptom

	Univariate model		Multiple model	
	OR (95%CI)	P	OR (95%CI)	P
Non overweight	Reference	Reference	Reference	Reference
Moderate increase	1.12 (0.83, 1.51)	0.442	1.12 (0.84, 1.50)	0.423
High increase	2.00 (1.47, 2.71)	< 0.001	1.61 (1.16, 2.24)	0.006
Mixed	1.40 (0.95, 2.05)	0.085	1.30 (0.85, 1.98)	0.215

Multiple model: Adjusted for age, gender, ethnicity, education level, poverty index (< 1.25, 1.25–3.49, ≥ 3.50), smoking status (current, former, never, < 100 cigarettes in life), alcohol consumption (yes or no), physical activity (meet the physical activity guidelines or not), diabetes, hypertension and stroke

OR, odds ratio

increase in PHQ-9 score (β = 0.34, 95%CI: [0.23, 0.44], $P < 0.001$) compared to the non-overweight pattern. After adjustment, the association remained significant (β = 0.20, 95% CI: [0.10, 0.31], $P < 0.001$) (Table S1).

Figure 2 illustrated the cumulative incidence for each BMI change pattern in the general population. Individuals with high increase BMI pattern were identified to have higher cumulative incidence rates than those with a non-overweight pattern. Similar trends were observed for both the moderate increase and mixed BMI change patterns. The log-rank test verified that these differences were statistically significant ($P < 0.001$).

Stratified analysis by gender and age

The risk of depressive symptom rose by 2.26 for high increase pattern among females (OR = 2.26, 95% CI: [1.51, 3.40], $P < 0.001$) compared with the non-overweight pattern, whereas no significant correlation between BMI change pattern groups and depressive symptom was identified among males (Table S2).

Age-stratified analysis (Table S3) indicated that the relationship between the high increase BMI change

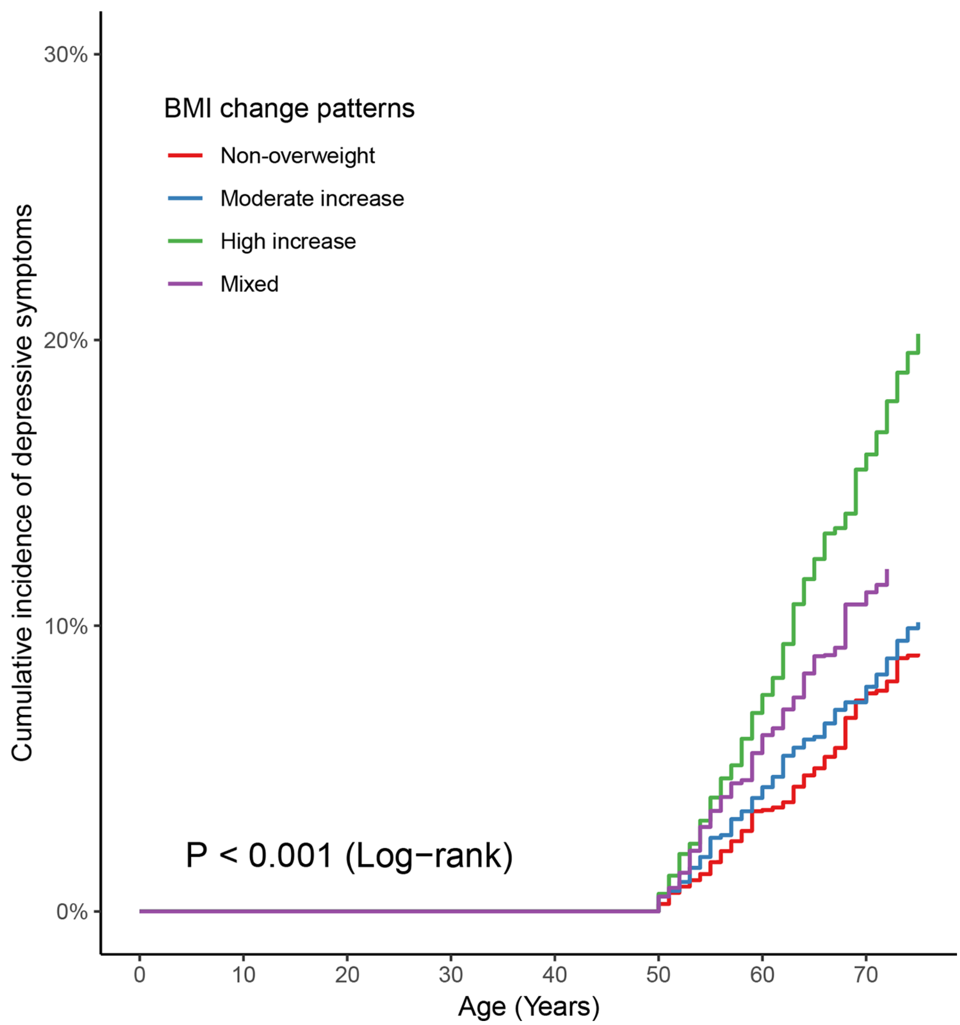

Fig. 2 Kaplan-Meier curves illustrating the cumulative incidence of depressive symptom according to BMI change patterns

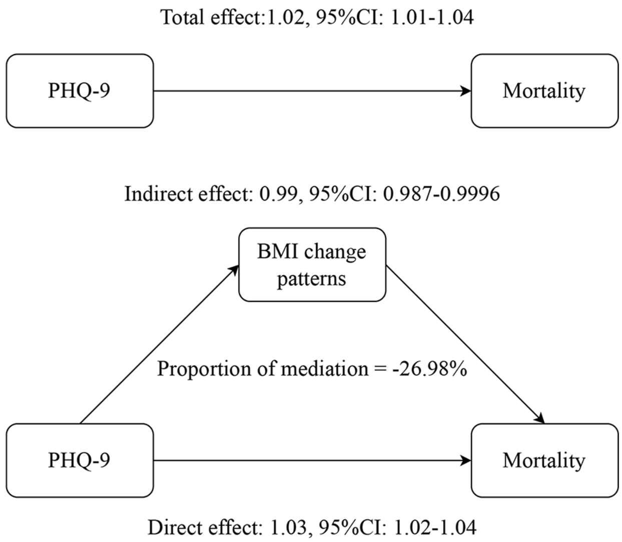

Fig. 3 Direct and indirect effects of BMI change pattern groups on mortality with depressive symptom as mediator. Models were adjusted for age, gender, ethnicity, education level, poverty index (< 1.25, 1.25–3.49, ≥ 3.50), smoking status (current, former, never, < 100 cigarettes in life), alcohol consumption (yes or no), physical activity (meet the physical activity guidelines or not), diabetes, hypertension and stroke. PHQ-9 the Patient Health Questionnaire

Table 3 BMI change pattern groups as a mediator of the association between the depressive symptoms and all-cause mortality

Mediation effect	Estimate	95% CI lower	95% CI upper	*P*-value
Total effect	1.02	1.01	1.04	< 0.001
Mediation effect	0.993	0.987	0.9996	0.038
Direct effect	1.03	1.02	1.0417	< 0.001

pattern and PHQ-9 score was most evident in participants aged 50–60, and the high increase pattern was related to a 1.83-point increase in depressive symptoms (OR = 1.83, 95% CI: [1.15, 2.91], $P = 0.011$) compared to the non-overweight pattern. And for those aged 70–80, the OR for depressive symptoms was 1.70 (95% CI: [1.05, 2.74]) for the high increase pattern.

The association of BMI change pattern groups and depressive symptoms with mortality

A total of 2016 deaths were reported among the 10,443 participants. Table S4 demonstrated that participants in the moderate increase BMI change pattern were less likely to die from all causes compared to those in the non-overweight pattern (hazard ratio (HR) = 0.81; 95% CI: 0.70–0.95). And each 1-point increase in depressive symptoms was related to a 3% increase in the risk of all-cause mortality (HR = 1.03, 95% CI: 1.02–1.05).

To explore the mediating role of depression in the association between BMI change patterns and all-cause mortality, a mediation analysis was performed. As shown in Fig. 3; Table 3, the indirect effect of depression was statistically significant (effect estimate = 0.99, $P < 0.05$), accounting for 26.98% of the total association between BMI change patterns and mortality. These findings support the hypothesis that depression partially mediates the relationship between long-term BMI changes and mortality risk. The conceptual mediation model depicting the pathways from BMI change patterns to mortality via depression is illustrated in Fig. 3.

Discussion

This study probed into the relationship between BMI change patterns and depression risk through a nationally representative sample of 10,448 U.S. individuals from NHANES. We detected that high increased BMI change pattern over adulthood were link to an increased risk of depression. Additionally, mediation analysis revealed that BMI change patterns played a modest role in linking depression to all-cause mortality.

While the long-term impact of obesity on depression in adulthood is understudied [9–11], previous research has shown some links between BMI trajectories and depression risk [10]. One notable study Perry et al. [10] identified an increased risk of depression at age 24 among participants experiencing significant BMI increases post-puberty. Similarly, our study identified a correlation between high increased BMI change patterns and depression risk. However, extended longitudinal studies and diverse population cohorts to fully elucidate the relationship between BMI change patterns and depression were also needed.

Sex-stratified analyses revealed notable differences, though evidence of effect modification was limited. Women in the high increased pattern exhibited an increased depression risk, consistent with prior studies [10]. For instance, Sayon-Orea et al. [11] discovered that women who saw notable increases in body size from childhood into adulthood were more likely to develop depression by age 40. This could be linked to greater body dissatisfaction and societal emphasis on women's appearance, amplifying vulnerability to depression [18]. In contrast, we observed no significant correlation between BMI change patterns and depressive symptoms in men, possibly due to underreporting of depressive symptoms or differences in help-seeking behaviors, as men are less likely to seek mental health support [19]. These observations underscore the importance of addressing gender-specific pathways in the obesity-depression relationship.

The complex interplay between depression and BMI is well-documented, with evidence suggesting a bidirectional relationship [20, 21]. Depressive symptoms can lead to weight gain through behavioral changes [22, 23], while obesity may increase depression risk due to social stigma and physiological factors. Research also suggests that the relationship varies by sex [24] and age [21]. For example, depressive symptoms have been associated with being underweight in men, while a U-shaped association has been observed in older adults [25]. These findings highlighted the multifaceted nature of the depression-BMI link, necessitating further exploration across different demographics.

Our study also explored how BMI change patterns and depressive symptoms interact to influence all-cause mortality risk. The results demonstrated that the connection between the risk of all-cause mortality and depressed symptoms may be mediated by BMI change patterns. Specifically, the PHQ-9 had a direct effect (1.03), an overall effect (1.02), and an indirect effect (0.99), mediated by BMI change patterns, on all-cause mortality risk. These results suggest that high BMI change patterns may contribute to a reduced onset of all-cause mortality risk. However, some findings have supported the "Fat and Jolly" hypothesis, suggesting that obesity might have a protective effect against depression [26]. Moreover, research by Bhaskaran et al. [27] showed that a BMI range of 24–27 kg/m² was link to a rise in mortality, particularly for mental health disorders. In line with this, individuals with depressive symptoms who were overweight or obese exhibited a two-fold greater vulnerability of death compared to non-depressive individuals with a BMI under 25 kg/m² [28–31]. Future research is required to verify these findings and explore the reasons behind them.

This study has limitations. First, despite our efforts to control for relevant confounders, there might be other factors influencing depressive symptoms and mortality risk that we could not account for. Second, depression was assessed using the PHQ-9, a reliable screening tool but not a diagnostic instrument. While a score of ≥10 on the PHQ-9 is highly sensitive and specific for major depressive disorder, it may underestimate true prevalence, particularly among individuals with severe depression who might be underrepresented [15]. Moreover, severe depression may have led to non-participation, further skewing prevalence estimates. As a result, the findings may underestimate true depression prevalence. Third, the reliance on self-reported data introduces potential biases due to cultural or individual factors. The cross-sectional design also restricts our capacity to extrapolate causal conclusions, and the follow-up period may not fully capture long-term mortality trends. While long-term studies often face survivor bias, they provide critical insights that short-term analyses cannot offer. Fourth, while the categorization of BMI into change pattern groups facilitates interpretability, we acknowledge that it may lead to loss of information from the original continuous variable. Future studies with richer longitudinal data and more time points could apply more advanced modeling strategies to capture the full spectrum of BMI dynamics over time. Additionally, the limited follow-up period may have resulted in an underestimation of fatality rates. For instance, the 40-year follow-up Canadian longitudinal study highlighted the impact of survivor bias [32, 33]. Future research should use longitudinal designs to more thoroughly explore the mediators of depression-related mortality risk.

Conclusion

This study identified BMI change patterns over adulthood and their influence on depression risk. Results indicate that high increased BMI change pattern increases depression risk. Monitoring BMI change patterns during adulthood could serve as a critical tool for assessing depression risk. Moreover, the BMI change patterns may mediate the relationship between depression and all-cause mortality risk, highlighting the importance of tracking BMI in adults with depression. Targeted mental health screenings and support for individuals with at-risk BMI change patterns could mitigate depression risk. Future research should investigate whether modifying BMI change patterns can lower depression incidence, which would help refine intervention strategies aimed at improving both physical and mental well-being.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12888-025-06924-y.

Supplementary Material 1: Figure S1. Survey-weighted pairwise differences in PHQ-9 scores between BMI change pattern groups, with 95% confidence intervals. Results are based on estimated marginal means with Tukey-adjusted P-values.

Supplementary Material 2

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Author contributions

Zhixiao Xu: Methodology, software, and writing-original draft preparation; Chengshui Chen: funding acquisition, and writing-review and editing; Xiong Lei: conceptualization, validation, data curation and writing-review and editing. All authors reviewed the manuscript.

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Data availability

Data could be publicly available from the website (https://wwwn.cdc.gov/nchs/nhanes/default.aspx).

Declarations

Ethics approval and consent to participate

NHANES were reviewed and approved by the National Center for Health Statistics Ethics Review Board, and all participants provided informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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