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ORIGINAL ARTICLE

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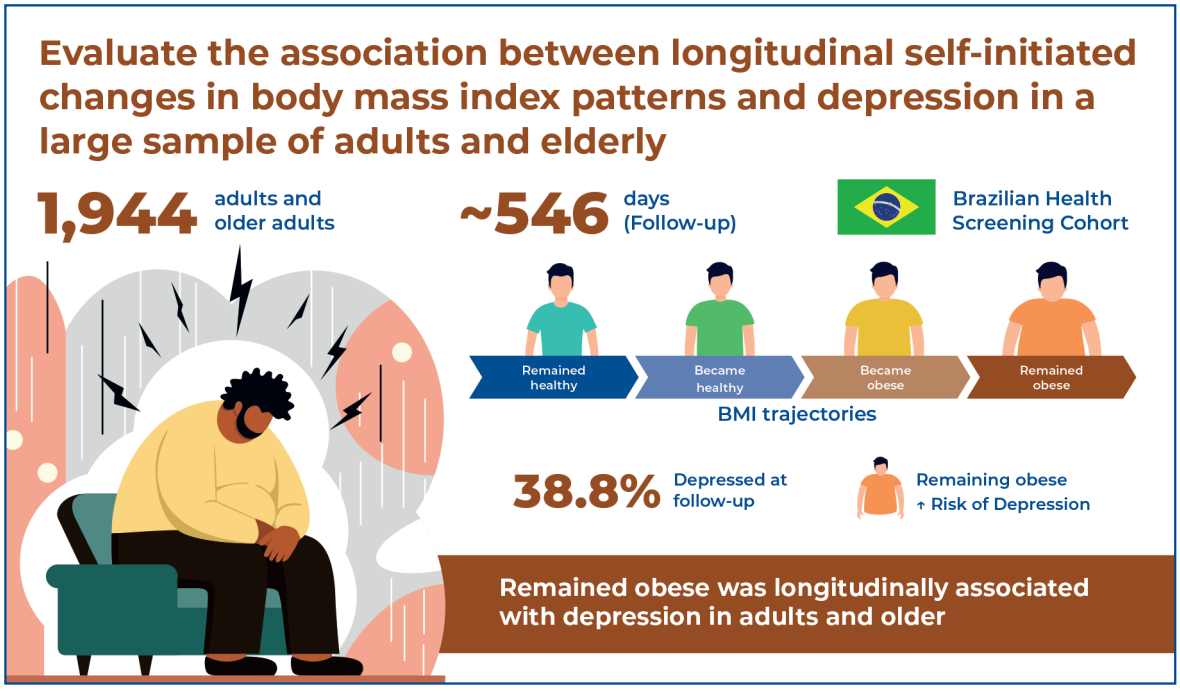

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In Brief

Persistence obesity over time was associated with higher odds of depression in adults and older individuals. Participants who remained obese had greater odds of depression than those who maintained or achieved a healthy body mass index. These findings suggest that sustained excess body weight may contribute to adverse mental health outcomes, potentially through metabolic, inflammatory, and psychosocial mechanisms. The results reinforce the importance of long-term weight management strategies not only for physical health but also for mental well-being across the lifespan.

Highlights

- Remaining obese over time was independently associated with higher odds of depression.

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Association between self-changes in body mass index patterns and depressive symptoms: a longitudinal follow-up study

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ABSTRACT

Objective: To evaluate the association between longitudinal self-initiated changes in body mass index patterns and depression in a large sample of adults and older individuals. **Methods:** Participants included 1,944 adults and older individuals with depressive symptoms at baseline who underwent routine health screening examinations. Depression was defined as Beck Depression Inventory-II scores ≥14. Body mass index, blood pressure, blood samples, alcohol consumption, smoking status, physical activity levels, perceived stress, depressive symptoms, and lower urinary tract symptoms were collected at baseline and follow-up (mean 545.9±152.9 days). Participants were stratified according to their body mass index patterns at baseline and follow-up as follows: i) remained healthy, ii) became healthy, iii) became obese, and iv) remained obese. Hierarchical logistic regression was performed to evaluate the association between body mass index patterns and depression at follow-up. **Results:** At follow-up, participants who remained obese had higher odds of depression (odds ratio: 1.33 95% confidence interval: 1.04-1.71, p=0.026) after adjustment for clinical and lifestyle variables. **Conclusion:** In participants who remained obese, obesity was longitudinally associated with depression in both adults and older individuals.

Keywords: Obesity; Depression; Body mass index; Chronic disease

INTRODUCTION

Depression is considered the leading cause of mental health-related illnesses and is associated with disability, reduced quality of life, medical comorbidities, and increased mortality worldwide. It has also been associated with low-grade inflammation and vascular risk, affecting approximately 300 million people.[1,2]

Depression is treated in primary care using psychological and pharmacotherapeutic interventions;[1] however, several well-known changes in modifiable lifestyle factors are associated with depression.[1-5] In a previous systematic review and meta-analysis of longitudinal studies[3] body mass index (BMI) showed a consistent positive association with depression. Lupino et al.[3] demonstrated that obese individuals at baseline (BMI ≥30kg/m^2) had increased odds of developing depression at follow-up (unadjusted odds ratio [OR]: 1.55; 95% confidence interval [95%CI]: 1.22-1.98, p≤0.001). This association was more pronounced for depressive disorders than for depressive symptoms (OR=2.15; 95%CI=1.48-3.12 *versus* OR=1.36; 95%CI=1.03-1.80, p=0.05,

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respectively). Overweight individuals at baseline (BMI=25-29.99kg/m^2) were also reported to have an increased risk of depression at follow-up (unadjusted OR=1.27; 95%CI=1.07-1.51, p=0.01), particularly among adults (OR=1.48; 95%CI=1.19-1.83, p≤0.001), but not among younger and older individuals (aged 20 years and over than 60 years). The study also included participants without depression at baseline who were followed up and screened for depression at follow-up.

To the best of our knowledge, the longitudinal associations between BMI and depression are not well defined,[3] as evaluating the longitudinal effect of any modifiable variables on depression requires some degree of depression to be considered at baseline. Furthermore, the association between self-reported changes in BMI patterns over time and depressive symptoms remains unclear. Previous studies have primarily examined BMI status at a single time point and have not clearly evaluated how different BMI trajectories, such as remaining obese, becoming healthy, becoming obese, or remaining healthy, are associated with depression over time. Given the importance of depression and BMI as markers of cardiovascular risk, low-grade inflammation and quality of life in adults and older individuals, it would be interesting to investigate whether individuals who maintain or change their BMI patterns present different risks of depression in a longitudinal follow-up design study.

OBJECTIVE

In this study, we aimed to analyze the association between longitudinal self-initiated changes in body mass index patterns (remained healthy, became healthy, became obese, and remained obese) and depression among Brazilian adults and older individuals. We hypothesized that those who became and remained obese would have higher odds of developing depression.

METHODS

This longitudinal cohort study analyzed changes in BMI patterns and depression at baseline and follow-up visits in Brazilian adults of both sexes. The time between visits ranged from 300 to 800 days.[6] The sample was collected from a large cohort of males and females aged ≥18 years who participated in health-screening initiatives at the Center for Preventive Medicine at *Hospital Israelita Albert Einstein* between 2008 and 2022. All procedures were approved by the ethics committee of the local Institutional Review Board (SGPP: 592924) and were conducted in accordance with the Declaration of Helsinki and the Brazilian National Research Ethics System Guidelines (CAAE: 77752224.0.0000.0071; 6.753.268). A waiver of informed consent was granted owing to the nature of this study and because the study posed no additional risk to participants. Additionally, the waiver was justified by the lack of opportunities for regular follow-up visits. Patient data confidentiality was guaranteed by strict internal protocols.

All participants voluntarily participated in health promotion and prevention programs. The database initially included 125,439 adults who had undergone health check-ups. Only individuals who returned for follow-up visits within 300-800 days were included, as described in a previous study.[6] For individuals with duplicate data (i.e., more than two health screenings), only the most recent data were considered. Participants who underwent only one health screening were excluded. We also restricted the interval between the first and second screenings to 300-800 days and excluded observations outside this range. If participants underwent three or more health screenings during the study period, only the first and most recent screenings were evaluated. We excluded records with missing BMI or depression data and individuals without some degree of depression at baseline (Beck Depression Inventory score <14 points). Finally, 1,944 adults and older individuals were included in the analysis, with a mean time between visits of 545.9±152.9 days.

Clinical data

Blood samples were collected after overnight fasting and analyzed as part of the routine clinical workflow. Laboratory procedures followed quality standards established by the Brazilian Ministry of Health. Laboratory analyses of glycated hemoglobin (HbA1C%), lipid profile (mg/dL), uric acid (UA,mg/dL), and ultrasensitive C-reactive protein (CRP,mg/dL) levels were performed using the Vitros platform automated laboratory system (Johnson & Johnson Clinical Diagnostics, New Brunswick). CRP levels were measured using the turbidimetric method on a nephelometry system (Dade Boehring, USA).

Blood pressure was evaluated in triplicate in the seated position after the participants had rested for at least 5 min, according to the recommendations of the American Heart Association.[7] The measurements were performed in both upper limbs using the auscultatory method with an aneroid sphygmomanometer, employing Korotkoff phase I and V sounds.

Medical records were accessed to identify the presence of comorbidities, such as systemic arterial

hypertension, diabetes mellitus, dyslipidemia, nonalcoholic fatty liver steatosis (NASH), smoking status, and medication use. If data were unavailable in the medical assessment, hypertension and diabetes were considered present when a patient self-reported the condition or reported chronic use of antihypertensive medication or antidiabetic medications, respectively.[8,9]

Lower urinary tract symptoms were analyzed using the International Prostatism Symptom Score (IPSS)[10] through face-to-face interviews.

Lifestyle data

Lifestyle factors were assessed using standardized questionnaires administered by trained professionals. Perceived stress was assessed using the Perceived Stress Scale (PSS-10),[11] alcohol consumption using the Alcohol Consumption Disorders Identification Test (AUDIT),[12] and physical activity using the International Physical Activity Questionnaire (IPAQ).[13]

Body mass index

BMI was calculated after obtaining the height and weight using the following formula: weight/height^2. Body weight was measured using InBody 230 equipment (Ottoboni®), and height was measured using a stadiometer. According to the World Health Organization recommendations[14] for nutritional status, BMI <18.5kg/m^2 was classified as underweight, BMI 18.5-24.9kg/m^2 as normal weight or healthy, BMI 25-29.9kg/m^2 as overweight or pre-obesity, BMI 30-34.9kg/m^2 as obesity class I, BMI 35-39.9kg/m^2 as obesity class II, and BMI >39.9kg/m^2 as obesity class III.

For the purposes of this study and in accordance with previous research.[15] participants with BMI ≥18.5 and <29.9kg/m^2 were classified as healthy, and those with BMI ≥30kg/m^2 were classified as obese. Finally, according to the baseline and follow-up visits, four groups were defined for the longitudinal assessment of self-initiated changes in BMI patterns: 1) remained healthy (healthy both at baseline and follow-up), 2) became healthy (obese at baseline and healthy at follow-up), 3) became obese (healthy at baseline and obese at follow-up), and 4) remained obese (obese both at baseline and follow-up).

Depression

The presence and level of depression were assessed by psychologists using the Beck Depression Inventory-II (BDI-II).[16] The questionnaire assessed depressive symptoms over the previous 15 days. The questions are rated on an ordinal scale ranging from 0 to 3, and the total score ranges from 0 to 63. In this study, the presence of depression was defined as BDI-II scores ≥14 points, including mild, moderate, and severe depression. The absence of depression was defined as a score of <14 points. In this study, at baseline, all participants had depression (BDI-II ≥14 points). For previously self-reported diagnoses of depression, the team of psychologists contacted the responsible healthcare professionals to confirm the information. All patients were asked about the use of antidepressants and anxiolytic medications and were evaluated at baseline and follow-up for all variables. Physicians and a multidisciplinary team (nutritionists, physical education professionals, psychologists, physiotherapists, and nurses) provided clinical and lifestyle counseling to encourage modifications in lifestyle habits and improve overall health. Patients with depression were advised to initiate or maintain professional follow-up.

Initially, we compared clinical and lifestyle variables at baseline with respect to self-initiated changes in BMI patterns. Subsequently, we compared the clinical and lifestyle variables at baseline in relation to the presence of depression. Finally, we examined the association between the studied variables and depression, with particular focus on the association between self-initiated changes in BMI patterns and depression.

Data analysis

The Shapiro-Wilk test was used to assess data normality. Categorical variables are presented as frequencies and percentages. Descriptive statistics for continuous variables are presented as means and standard deviations. Categorical variables were compared using chi-square and likelihood ratio tests. To compare numerical variables across BMI pattern groups, we used a one-way ANOVA, and for multiple comparisons, we used the Bonferroni test. Student's t-test was used to compare numerical variables according to depression status.

Independent variables were measured at two time points (baseline and follow-up); thus, longitudinal variables were constructed to reflect changes over time. The association between self-initiated changes in BMI patterns and depression was estimated using hierarchical regression, and results were expressed as OR and 95%CI. Baseline values of age (each year), sex, hypertension, diabetes, tabagism status, dyslipidemia, alcohol consumption (AUDIT), perceived stress (PSS-10), lower urinary tract symptoms (IPSS), and physical activity levels (IPAQ) were used as covariates in the

hierarchical models. In the first step, adjustments were made for age (each year) and sex. In the second step, the model was adjusted for age (each year), sex, presence of hypertension, diabetes, dyslipidemia, and lower urinary tract symptoms. In the final step, the model was adjusted for age (each year), sex, presence of hypertension, diabetes, dyslipidemia, lower urinary tract symptoms, smoking status, alcohol consumption, perceived stress, physical activity levels, and self-initiated changes in BMI patterns. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SPSS for Windows (version 24.0; IBM Corp., Armonk, NY, USA).

RESULTS

At follow-up, 756 (38.8%) participants had depression. Additionally, 1,473 (75.8%) participants remained healthy, 83 (4.3%) became obese, 55 (2.8%) became healthy, and 333 (17.1%) remained obese. Table 1 presents a comparison of clinical and lifestyle data according to self-initiated changes in BMI patterns. Participants who remained obese showed a higher prevalence of diabetes ($p<0.001$), alcohol consumption ($p=0.029$), and lower urinary tract symptoms ($p=0.040$), whereas obese individuals had more tabagism ($p<0.001$). Furthermore, individuals who remained healthy had lower glycated hemoglobin

Table 1. Comparison of clinical and lifestyle data at baseline in relation to self-changes in BMI patterns (n=1,944)

	Remained healthy	Became healthy	Became obese	Remained obese	Total	p value
Sex						<0.001[&]
Female	683 (46.4)	18 (32.7)	43 (51.8)	97 (29.1)	841 (43.3)	
Male	790 (53.6)	37 (67.3)	40 (48.2)	236 (70.9)	1.103 (56.7)	
Presence of hypertension						<0.001[&]
Yes	141 (9.6)	17 (30.9)	11 (13.3)	92 (27.6)	261 (13.4)	
Presence of diabetes						<0.001[#]
Yes	49 (3.3)	5 (9.1)	4 (4.8)	39 (11.7)	97 (5)	
Presence of dyslipidemia						0.007[&]
Yes	534 (36.3)	28 (50.9)	33 (39.8)	149 (44.7)	744 (38.3)	
Physical activity levels						0.001[#]
Innactive	380 (26.2)	24 (44.4)	27 (32.9)	108 (32.9)	539 (28.2)	
Insufficiently active	505 (34.8)	21 (38.9)	26 (31.7)	111 (33.8)	663 (34.6)	
Active	469 (32.3)	9 (16.7)	24 (29.3)	99 (30.2)	601 (31.4)	
Higly active	96 (6.6)	0 (0)	5 (6.1)	10 (3)	111 (5.8)	
Tabagism status						0.234[#]
Yes	132 (9)	4 (7.3)	12 (14.6)	24 (7.2)	172 (8.9)	
Perceived stress						0.176
Yes	1.128 (80.8)	41 (80.4)	63 (77.8)	242 (75.4)	1.474 (79.7)	
Alcohol consumption						0.029[#]
Hazardous	175 (12)	5 (9.1)	15 (18.3)	38 (11.5)	233 (12.1)	
Moderate-severe	37 (2.5)	5 (9.1)	2 (2.4)	18 (5.5)	62 (3.2)	
Lower urinary tract symptoms						0.040[#]
Mild	395 (90.4)	22 (88)	18 (94.7)	112 (81.8)	547 (88.5)	
Moderate	39 (8.9)	2 (8)	1 (5.3)	25 (18.2)	67 (10.8)	
Severe	3 (0.7)	1 (4)	0 (0)	0 (0)	4 (0.6)	
Mean±SD (n)						
Age (y)	41.44±8.83 (1.473)	44.2±8.14 (55)	41.11±8.87 (83)	42.84±8.88 (333)	41.74±8.84 (1.944)	0.009
HbAlc (%)	5.40±0.55 (1.118)[†‡]	5.66±1.03 (42)	5.38±0.38 (66)	5.6±0.81 (282)	5.42±0.63 (1.508)	<0.001*
TC (mg/dL)	190.45±35.88 (1.470)	190.11±36.34 (55)	195.73±43.1 (83)	194.61±35.84 (332)	191.38±36.24 (1.940)	0.181
LDL (mg/dL)	114.45±32.73 (1.470)	113.33±33.83 (55)	123.38±38.6 (83)	119.48±31.80 (332)	115.66±32.95 (1.940)	0.01*
HDL (mg/dL)	52.71±15.50 (1.469)[†‡]	45.55±11.81 (55)	48.43±11.33 (83)	44.92±11.24 (332)	50.98±14.92 (1.939)	<0.001*
TG (mg/dL)	118.34±78.71 (1.470)[†‡]	162.98±82.21 (55)[§]	120.81±51.49 (83)[#]	160.75±112.14 (332)	128.97±86.2 (1.940)	<0.001*
UA (mg/dL)	4.99±1.36 (844)[†‡]	5.88±1.82 (38)[§]	4.93±1.24 (47)[#]	5.88±1.42 (211)	5.19±1.43 (1.140)	<0.001*
Ultrasensitive c-reactive protein high (mg/dL)	0.24±0.41 (828)[‡]	0.29±0.23 (34)	0.28±0.30 (48)	0.45±0.65 (178)	0.27±0.46 (1.088)	<0.001*

*ANOVA and multiple-comparison using Bonferroni test; [&] χ^2 test; [#] likelihood ratio; [†] Remained healthy *versus* Became healthy; [‡] Remained healthy *versus* Remained obese; [§] Became healthy *versus* Became obese; [#] Became obese *versus* Remained obese.

SD: standard deviation, N: sample size, TC: total cholesterol, HDL: high-density lipid, TG: triglyceride, LDL: low-density lipids, HbAlc: glycosylated hemoglobin, UA: uric acid.

(5.40%±0.55% *versus* 5.66%±1.03%, p<0.001) and triglycerides (118.34±78.71 *versus* 162.98±82.21mg/dL, p<0.001), uric acid (4.99±1.36 *versus* 5.88±1.82mg/dL, p<0.001), and higher HDL cholesterol (52.71±15.50 *versus* 45.55±11.81mg/dL, p<0.001) than those who became healthy. The individuals who remained healthy had lower glycated hemoglobin (5.40%±0.55% *versus* 5.6%±0.81%, p<0.001), triglycerides (118.34±78.71 *versus* 160.75±112.14mg/dL, p<0.001), uric acid (4.99±1.36 *versus* 5.88±1.42mg/dL, p<0.001), ultrasensitive c-reactive protein high (0.24±0.41 *versus* 0.45±0.65mg/dL, p<0.001), and higher HDL cholesterol (52.71±15.50 *versus* 44.92±11.24mg/dL, p<0.001) than individuals who remained obese. Individuals who became healthy had higher triglycerides (162.98±82.21 *versus* 120.81±51.49mg/dL, p <0.001) and uric acid (5.88±1.82 *versus* 4.93±1.24mg/dL, p<0.001) than those who became obese. Finally, individuals who became obese had lower triglycerides (120.81±51.49 *versus* 160.75±112.14mg/dL, p<0.001) and uric acid (4.93±1.24 *versus* 5.88±1.42mg/dL, p<0.001) than those who remained obese.

Table 2 presents a comparison of the clinical and behavioral data at follow-up according to depression

Table 2. Comparison of clinical and lifestyle data at follow-up in relation to depression (n=1,944)

Variables	Depression		Total	p value
	Absence	Presence		
Sex				0.001[&]
Female	480 (40.2)	362 (47.9)	842 (43.2)	
Male	714 (59.8)	394 (52.1)	1.108 (56.8)	
Hypertension				0.546
Yes	156 (13.1)	106 (14)	262 (13.4)	
Diabetes				0.933
Yes	59 (4.9)	38 (5)	97 (5)	
Dyslipidemia				0.358
Yes	467 (39.1)	280 (37)	747 (38.3)	
Smoking status				0.614
Yes	102 (8.6)	70 (9.3)	172 (8.9)	
Perceived stress				0.002[&]
Yes	876 (77.4)	603 (83.4)	1.479 (79.7)	
Alcohol consumption				0.998
Mild	1.003 (84.6)	635 (84.7)	1.638 (84.6)	
Hazardous	145 (12.2)	91 (12.1)	236 (12.2)	
Moderate-severe	38 (3.2)	24 (3.2)	62 (3.2)	
Physical activity levels				0.207
Inactive	316 (26.9)	224 (30.1)	540 (28.1)	
Low active	404 (34.4)	263 (35.3)	667 (34.8)	
Active	379 (32.3)	222 (29.8)	601 (31.3)	
High active	75 (6.4)	36 (4.8)	111 (5.8)	
Lower urinary tract symptoms				0.038[#]
Mild	362 (89.6)	187 (85.8)	549 (88.3)	
Moderate	38 (9.4)	31 (14.2)	69 (11.1)	
Severe	4 (1)	0 (0)	4 (0.6)	
Self-changes in BMI patterns				0.109
Remained healthy	919 (77.2)	554 (73.5)	1.473 (75.8)	
Became healthy	37 (3.1)	18 (2.4)	55 (2.8)	
Became obese	46 (3.9)	37 (4.9)	83 (4.3)	
Remained obese	188 (15.8)	145 (19.2)	333 (17.1)	
Mean±SD (n)				
Age	42.1±8.76 (1.194)	41.22±8.97 (756)	41.76±8.85 (1.944)	0.033*
HbAlc (%)	5.46±0.71 (909)	5.37±0.48 (601)	5.42±0.63 (1.510)	0.004*
TC (mg/dL)	190.88±35.91 (1.191)	192.32±36.71 (755)	191.44±36.22 (1.946)	0.392
LDL (mg/dL)	115.50±32.96 (1.191)	115.94±32.92 (755)	115.67±32.94 (1.946)	0.776
HDL (mg/dL)	50.74±14.65 (1.190)	51.3±15.31 (755)	50.96±14.91 (1.945)	0.423
TG (mg/dL)	126.19±88.02 (1.191)	128.89±83.98 (755)	127.24±86.47 (1.946)	0.503
UA (mg/dL)	5.22±1.45 (718)	5.12±1.40 (427)	5.19±1.43 (1.145)	0.270
Ultrasensitive c-reactive protein high (mg/dL)	0.25±0.41 (682)	0.33±0.55 (411)	0.28±0.47 (1.093)	0.007*

*Student's t-test; [&] χ^2 test; # likelihood ratio.
SD: standard deviation, N: sample size, TC: total cholesterol, HDL: high-density lipid, TG: triglyceride, LDL: low-density lipids, HbAlc: glycosylated hemoglobin, UA: uric acid.

status. Individuals with depression at follow-up were younger (41.22±8.97 *versus* 42.1±8.76 years, p=0.033), had a higher proportion of females (p<0.001), showed higher values of ultrasensitive c-reactive protein high (0.33±0.55 *versus* 0.25±0.41, p=0.007), and had worse lower urinary tract symptom scores (p=0.038). Additionally, individuals with depression at follow-up reported higher perceived stress levels (p=0.002).

Table 3 presents the hierarchical regression adjusted for clinical and lifestyle variables, analyzing only the variables associated with statistically significant values of depression. Female sex (OR=1.402; 95%CI=1.157-1.699, p<0.001), perceived stress (OR=1.404; 95%CI=1.100-1.791, p=0.006), and self-initiated changes in BMI patterns – specifically remaining obese (OR=1.331; 95%CI=1.036-1.711, p=0.026) were associated with higher odds of depression.

Table 3. Association between clinical and lifestyle data and depression (n=1,944)

	OR (95%CI)	p value
Age (each year)‡	0.990 (0.979-1.000)	0.049
Sex (female)	1.355 (1.127-1.628)	0.001
Age (each year)†	0.987 (0.976-0.998)	0.023
Sex (female)	1.374 (1.139-1.658)	<0.001
Sex (female)#	1.402 (1.157-1.699)	<0.001
Perceived stress	1.404 (1.100-1.791)	0.006
Changes in BMI Remained healthy (reference)		
Became healthy	0.866 (0.477-1.573)	0.636
Became obese	1.293 (0.820-2.038)	0.269
Remained obese	1.331 (1.036-1.711)	0.026

Hierarchical regression test.
‡ Adjusted for age (baseline) and sex; † Adjusted for age (baseline), sex, hypertension (baseline), diabetes (baseline), dyslipidemia (baseline), and lower urinary tract symptoms (baseline); # Adjusted for age (baseline), sex, hypertension (baseline), diabetes (baseline), dyslipidemia (baseline), lower urinary tract symptoms (baseline), smoking status (baseline), alcohol consumption (baseline), perceived stress (baseline), physical activity levels (baseline), and self-changes in body mass index patterns (baseline).
OR: odds ratio, 95%CI: 95% confidence interval.

DISCUSSION

The current study is among the first follow-up analysis to investigate the association between self-initiated changes in BMI patterns and depression in adults and older individuals. We found that individuals who remained obese had higher odds of depression. The longitudinal association between changes in BMI patterns and depression persisted after multistep adjustments for age, chronic diseases (diabetes, hypertension, dyslipidemia, and lower urinary tract symptoms), and lifestyle factors closely associated with low-grade inflammation.[6]

Derby et al.[15] also demonstrated that changes in BMI patterns are associated with lower inflammatory levels. Van Itallie[17] and Hubert et al.[18] suggested that obesity is associated with adverse lipid profiles, hypertension, and diabetes, and may be independently associated with atherosclerotic heart disease. Therefore, our results reinforce the negative effects of self-changing BMI patterns (remaining obese), which may contribute to low-grade inflammation and cardiovascular risk and, consequently, the risk of depression in adults and the older individuals. The mechanisms explaining how obesity worsens depression include the chronic responses of several inflammatory proteins (cytokines), such as IL-6, TNF-a, and CRP[19-21] and decreased brain-derived neurotrophic factor (BNDF). These biological alterations are associated with structural and functional changes in the hippocampus, contributing to the severity of depression and the development of chronic diseases. Specific symptoms of obesity include increased and altered appetite, insomnia, pain, decreased self-esteem, distorted self-image, reduced social interaction, and an increased risk of depression.[22] Thus, chronic exposure to obesity may lead to higher baseline levels of circulating inflammatory markers and worse BDNF levels, and may also act as a cofactor for other cognitive aspects such anxiety,[23] stress,[24] and clinical conditions including hypertension[25] and diabetes,[26] leading to systemic low-grade inflammation, depression, and cardiovascular risk.

Our findings also demonstrate that perceived stress is associated with depression. Stressful life events can induce psychological and physiological changes, including the activation of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system.[24] Hyperactivity of the HPA axis is one of the most frequently observed neurobiological alterations in patients with depression.[24] Neural signals originating from higher cortical brain regions are transmitted to the hypothalamus through the limbic system, leading to the release of neurotransmitters such as serotonin, norepinephrine, and acetylcholine. This process activates specific cells of the paraventricular nucleus in the hypothalamus, stimulating the secretion of corticotropin-releasing factors, which exert their effects on multiple aspects of brain function, such as neuron survival, neurogenesis, size of the hippocampus, emotional events, negative feedbacks and peripheral functions, including metabolism and immunity.[27] Chronic exposure to stress induces a reduction in hippocampal volume and a decrease in the expression of neurotrophic factors, and inhibits neurogenesis in the adult brain.[27]

Finally, we observed that female sex was associated with depression, consistent with the results of previous studies.[28-30] Women may experience specific forms of depression-related conditions, such as premenstrual dysphoric disorder, postpartum depression, postmenopausal depression, and anxiety, which are associated with hormonal changes that may contribute to the development of depression.[30]

This study is among the first to investigate the association between self-reported changes in BMI and depression in a large Brazilian cohort. We believe that cultural and environmental factors can influence these findings, including the growing alienation and stress present in industrial societies and cultural beliefs about human behavior, and suggesting that self-changes in BMI patterns may play an important preventive role in depression, as well as other modifiable factors associated with depression, such as perceived stress.

The strengths of the present study include a large cohort of individuals aged 18 years, with detailed demographic, clinical, and lifestyle data collected at repeated measurements over 300-800 days. A more precise investigation of the variables of interest, particularly BMI patterns, was possible due to the adjustment for several confounding factors in our sample. In addition, validated questionnaires and standardized clinical assessments were carried out by trained physicians and healthcare professionals. The use of hierarchical regression model incorporating clinical, demographic, and lifestyle factors allowed for a multifactorial understanding of depression in our population.

This study has certain limitations that deserve consideration when interpreting the results. The use of self-reported questionnaires to assess lifestyle data as opposed to objective measures may be considered a limitation of this study. Additionally, family history of depression, chronic pain, and sleep-related variables were not included, which could influence the observed associations. Despite the temporal sequence of the study design and use of important confounding factors, it was not possible to adopt a causal relationship from our findings. Furthermore, data on race and ethnicity were not obtained, and the study population consisted of individuals with access to health insurance, which may limit the generalizability of the findings to the broader Brazilian population. Future studies should examine longitudinal effects of self-initiated changes in BMI patterns using objective measures of depression in more diverse populations.

Finally, we hope that the findings may contribute to both clinical and public health strategies. Despite its cross-sectional nature, the results of this study could serve as a preventive measures to reduce the risk of depression and improve lifestyle habits.

CONCLUSION

The present study suggests that the self-initiated changes in body mass index patterns were associated with depression in adults and older individuals. Participants who remained obese had higher odds of depression. Female sex and higher perceived stress were also associated with depression.

The association between obesity and depression has profound preventive clinical implications for planning strategies and education programs based on weight loss aimed at reducing the risk of atherosclerotic cardiovascular disease and improving lifestyle habits.

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DATA AVAILABILITY

Data are available to reviewers upon request.

AUTHORS' CONTRIBUTION

Rafael Mathias Pitta: conceptualization, data curation, formal analysis, investigation, methodology, resources, and writing the original draft. Oskar Grau Kaufmann: supervision, writing, reviewing, and editing. Eduardo Rossato de Victo: validation and visualization. Gabriel Grizzo Cucato and Raphael Mendes Ritti-Dias: project administration and supervision. Luana de Lima Queiroga: validation and visualization. Nelson Wolosker: project administration, supervision, writing, review, and editing.

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REFERENCES

1. Pearce M, Garcia L, Abbas A, Strain T, Schuch FB, Golubic R, et al. Association Between Physical Activity and Risk of Depression: A Systematic Review and Meta-analysis. JAMA Psychiatry. 2022;79(6):550-9.

2. Heissel A, Heinen D, Brokmeier LL, Skarabis N, Kangas M, Vancampfort D, et al. Exercise as medicine for depressive symptoms? A systematic review and meta-analysis with meta-regression. Br J Sports Med. 2023;57(16):1049-57.
3. Luppino FS, de Wit LM, Bouvy PF, Stijnen T, Cuijpers P, Penninx BW, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. Arch Gen Psychiatry. 2010;67(3):220-9.
4. Werneck AO, Christofaro DG, Ritti-Dias RM, Cucato GG, Stubbs B, Oyeyemi AL, et al. Does physical activity influence the association between depressive symptoms and low-grade inflammation in adults? A study of 8,048 adults. Physiol Behav. 2020;223:112967.
5. Werneck AO, Vancampfort D, Stubbs B, Silva DR, Cucato GG, Christofaro DG, et al. Prospective associations between multiple lifestyle behaviors and depressive symptoms. J Affect Disord. 2022;301:233-9.
6. Fernandes RA, Ritti-Dias RM, Balagopal PB, Conceição RD, Santos RD, Cucato GG, et al. Self-initiated physical activity is associated with high sensitivity C-reactive protein: A longitudinal study in 5,030 adults. Atherosclerosis. 2018;273:131-5.
7. James PA, Oparil S, Carter BL, Cushman WC, Dennison-Himmelfarb C, Handler J, et al. 2014 evidence-based guideline for the management of high blood pressure in adults: report from the panel members appointed to the Eighth Joint National Committee (JNC 8). JAMA. 2014;311(5):507-20. Erratum in: JAMA. 2014;311(17):1809.
8. Pitta RM, Kaufmann O, Louzada AC, Astolfi RH, de Lima Queiroga L, Ritti Dias RM, et al. The association between physical activity and erectile dysfunction: A cross-sectional study in 20,789 Brazilian men. PLoS One. 2022;17(11):e0276963.
9. Pitta RM, de Lima Queiroga L, Louzada AC, Ritti-Dias RM, Kaufmann OG, Wolosker N. What are the Main Risk Factors Associated with Erectile Dysfunction in the Elderly? A Cross-Sectional Study of 2436 Brazilian Elderly Men. Clin Interv Aging. 2023;18:1047-54.
10. Silva CS, Freitas KS, R Ribeiro AP, Gomes CM, Bessa Junior J. Transcultural adaptation and validation of the questionnaire "Urgency, Weak stream, Incomplete emptying and Nocturia (UWIN)" for the Brazilian Portuguese. PeerJ. 2020;8:e9039.
11. Reis RS, Hino AA, Añez CR. Perceived stress scale: reliability and validity study in Brazil. J Health Psychol. 2010;15(1):107-14.
12. Machado PM, Campelo CL, Oliveira JV, Batista RF, Simões VM, Santos AM. Analysis of the AUDIT factor structure in adolescents between 18 and 19 years. Rev Saude Publica. 2021;55:27.
13. Hallal PC, Simoes E, Reichert FF, Azevedo MR, Ramos LR, Pratt M, et al. Validity and reliability of the telephone-administered international physical activity questionnaire in Brazil. J Phys Act Health. 2010;7(3):402-9.
14. World Health Organization (WHO). Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser. 1995;854:1-452.
15. Derby CA, Mohr BA, Goldstein I, Feldman HA, Johannes CB, McKinlay JB. Modifiable risk factors and erectile dysfunction: can lifestyle changes modify risk? Urology. 2000;56(2):302-6.
16. Gomes-Oliveira MH, Gorenstein C, Lotufo Neto F, Andrade LH, Wang YP. Validation of the Brazilian Portuguese version of the Beck Depression Inventory-II in a community sample. Braz J Psychiatry. 2012;34(4):389-94.
17. Van Itallie TB. Health implications of overweight and obesity in the United States. Ann Intern Med. 1985;103(6 (Pt 2)):983-8.
18. Hubert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart Study. Circulation. 1983;67(5):968-77.
19. Wang T, He C. Pro-inflammatory cytokines: the link between obesity and osteoarthritis. Cytokine Growth Factor Rev. 2018;44:38-50.
20. Cavanagh A, Wilson CJ, Kavanagh DJ, Caputi P. Differences in the Expression of Symptoms in Men Versus Women with Depression: A Systematic Review and Meta-analysis. Harv Rev Psychiatry. 2017;25(1):29-38.
21. Albert PR. Why is depression more prevalent in women? J Psychiatry Neurosci. 2015;40(4):219-21.
22. Yusufov M, Dalrymple K, Bernstein MH, Walsh E, Rosenstein L, Chelminski I, et al. Body mass index, depression, and suicidality: the role of self-esteem in bariatric surgery candidates. J Affect Disord. 2017;208:238-47.
23. Amiri S, Behnezhad S. Obesity and anxiety symptoms: a systematic review and meta-analysis. Neuropsychiatr. 2019;33(2):72-89.
24. Bjerkeset O, Romundstad P, Evans J, Gunnell D. Association of adult body mass index and height with anxiety, depression, and suicide in the general population: the HUNT study. Am J Epidemiol. 2008;167(2):193-202.
25. Litwin M, Kułaga Z. Obesity, metabolic syndrome, and primary hypertension. Pediatr Nephrol. 2021;36(4):825-37.
26. Piché ME, Tchernof A, Després JP. Obesity Phenotypes, Diabetes, and Cardiovascular Diseases. Circ Res. 2020;126(11):1477-1500. Erratum in: Circ Res. 2020;127(3):e107. Review.
27. Kofod J, Elfving B, Nielsen EH, Mors O, Köhler-Forsberg O. Depression and inflammation: correlation between changes in inflammatory markers with antidepressant response and long-term prognosis. Eur Neuropsychopharmacol. 2022;54:116-25.
28. Sharma VK, Das S, Mondal S, Goswami U, Gandhi A. Effect of Sahaj Yoga on neuro-cognitive functions in patients suffering from major depression. Indian J Physiol Pharmacol. 2006;50(4):375-83.
29. Fiske A, Wetherell JL, Gatz M. Depression in older adults. Annu Rev Clin Psychol. 2009;5(1):363-89.
30. Mohammadi S, Seyedmirzaei H, Salehi MA, Jahanshahi A, Zakavi SS, Dehghani Firouzabadi F, et al. Brain-based Sex Differences in Depression: A Systematic Review of Neuroimaging Studies. Brain Imaging Behav. 2023;17(5):541-69.