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Article

Interrelated Dynamics of Psychological, Sociodemographic, and Physical Activity Factors in Post-Bariatric Weight Regain

Maria Eveline Nascimento Pereira Vieira[1]; Igor Maciel Silva[2]; Joaquim Máximo da Silva[3]; Juan Bringel Gonçalves Lobo[4]; Nélio Barreto Vieira[5]

1 Nutritionist. Centro Universitário Maurício de Nassau; eveline09-menp@hotmail.com

2 Medical Student. Universidade Federal do Cariri – UFCA; igor.maciel@aluno.ufca.edu.br

3 Medical Student. Universidade Federal do Cariri – UFCA; joaquim.maximo@aluno.ufca.edu.br

4 Medical Student. Universidade Federal do Cariri – UFCA; bringel.juan@aluno.ufca.edu.br

5 Doctor of Health Sciences. Universidade Federal do Cariri – UFCA. Brazil; nelio.barreto@ufca.edu.br*.

A R T I C L E I N F O

Keywords:

Obesity;

Bariatric surgery;

Adaptive complex system;

Network analysis.

A B S T R A C T

Weight regain occurs in approximately 10 to 20% of individuals following bariatric surgery and remains a complex and multifactorial phenomenon, which makes both its understanding and management particularly challenging. This study aimed to explore the associations between weight regain and psychological, sociodemographic, and behavioral factors, using a network analysis approach. The study sample comprised 124 patients of both sexes, with a mean age of 39 ± 9.1 years, all of whom had undergone bariatric surgery at least 18 months prior. After providing informed consent, participants completed a series of questionnaires via the Google Forms platform. The findings revealed a negative correlation between weight regain and indicators of depression, anxiety, stress, binge eating, and specific personality traits, including negative affectivity (−0.182), detachment (−0.078), antagonism (−0.107), disinterest (−0.198), and psychoticism (−0.158). Measures of centrality highlighted disinterest and negative affectivity, along with most items on the depression, anxiety, and stress scale, as having the highest expected influence (ranging from 1.043 to 1.502). These variables emerged as key targets for intervention and deserve greater clinical attention from healthcare professionals.

* Correspondence to: Nélio Barreto Vieira.
E-mail addresses: nelio.barreto@ufca.edu.br
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1. Introduction

Obesity is currently regarded as a global epidemic, with approximately 1.9 billion individuals affected worldwide, according to the World Health Organization (WHO) [1]. This condition has been linked to a significant decrease in life expectancy, estimated at around 10 to 15 years [2]. While there have been meaningful advances in drug-based therapies for obesity, bariatric surgery remains the primary strategy for patients who do not respond to conventional treatments [3]. Nevertheless, studies consistently show that about 10 to 20% of individuals experience weight regain approximately 18 months following the surgical procedure [4,5]. This outcome reflects the multifactorial nature of recovery, which makes it challenging to precisely isolate the effect of each variable contributing to postoperative weight recurrence. Despite these complexities, there is strong and growing evidence from epidemiological studies, clinical trials, and meta-analyses supporting the link between psychological factors and obesity [6,7].

Research has pointed to anxiety and depression [8,9], elevated psychological stress [10], diminished self-image, and difficulty applying adaptive coping strategies in response to daily life problems [11,12] as contributors to weight regain. Personality traits associated with negative emotional states [13] and their connection to physical inactivity [14] have also been reported in this context. Among all these factors, psychological characteristics represent one of the most difficult domains to evaluate, especially given the limited number of medical studies focusing specifically on this subject [15–17].

The concept of complex systems (CS) provides a useful framework for interpreting weight regain after bariatric surgery. These systems are composed of many interacting elements whose combined behavior leads to emergent properties, which cannot be fully understood by analyzing each component in isolation. Complex systems are commonly encountered in fields such as physics, biology, sociology, and economics, and their investigation often requires multidisciplinary approaches. CS involves heterogeneous elements that interact in non-linear ways and are highly sensitive to minor changes in their components. Accordingly, weight regain following bariatric surgery can be considered a complex system in itself [18].

In light of this, network analysis offers a promising statistical tool to explore the interplay between system elements. It enables researchers to visualize and interpret how variables are connected, as well as to detect patterns and structures that emerge from these interactions. Previous studies have already employed health network analysis to investigate correlations between variables related to obesity within a complex system perspective [16,19,20], opening new pathways for multidisciplinary research in this area.

Based on this conceptual and empirical background, the present study aimed to examine the associations between weight regain and psychological variables (including anxiety, stress, depression, eating behavior, and especially personality traits), sociodemographic characteristics, and levels of physical activity using a network analysis approach in patients who had undergone bariatric surgery and subsequently experienced weight regain.

2. Materials and Methods

This is a quantitative and cross-sectional study. To improve the process of scientific transparency, the STROBE protocol [19] and CHERRIES [20] were used.

2.1. Participants

The sample was composed of convenience. Inclusion criteria were: patients aged at least 18 years old, of both sexes, operated by the same surgeon, by Gastric Bypass or Sleeve techniques and who accepted to voluntarily participate in the study. Patients with post-surgical time less than 18 months were excluded from the sample. Invitations were sent to bariatric patients Brazilians over 18 months old, of which only 124 voluntarily agreed to participate in the research, and it is emphasized that of this total 14.5% of the patients were operated by the Sleeve technique and 85.5% by the Bypass technique. The individuals in the sample had a mean age of 39 ± 9.1 years, of both sexes, with a minimum post-surgical time of 18 months and a maximum of 144 months, followed by the multidisciplinary health team of the Nucleus – Health Services located in the municipality of Juazeiro do Norte, in the Metropolitan region of Cariri, Ceará, Brazil.

2.2. Procedures

An online invitation to participate in this study was directed, by e-mail or social network application, individually to each participant, where they were informed about the objectives, protocols and procedures of the research. After voluntary consent to participate in this study, the interviewees answered the instruments directly on the Google Forms online platform.

2.3. Measures

2.3.1. Sociodemographic and clinical factors

A questionnaire was used to obtain information on the clinical (history of chronic diseases and medication use) and socio-economic variables: age, gender, marital status, income and years of study.

2.3.2. Eating Behavior

To evaluate eating behavior, two instruments were applied: Bulimic Investigatory Test of Edinburgh (BITE) [21], in its version in Portuguese [22], and the Periodic Binge Eating Scale (ECAP) [23] also in its Brazilian version [24].

The BITE is a self-administered questionnaire, composed of two scales: one of symptoms (composed of 30 items) and one of severity (3 dimensional items), the sum of the two scores produces a total score. The symptom scale ranges from 0 to 30 points, and "yes" answers represent the presence of symptom, worth 1 point, and the "no" responses represent no symptom (0). In questions 1, 13, 21, 23 and 31, it is scored inversely. After evaluation, the scale allows three classifications: High (20 points or more): considered a high score with the presence of compulsive eating behavior and a great possibility of fulfilling diagnostic criteria for bulimia nervosa. Mean (10 to 19 points):

suggests unusual dietary pattern, usually, without the presence of all criteria for bulimia classification. Low (below 10 points): behavior within normal limits [21,22].

ECAP is an appropriate instrument to distinguish individuals who are candidates for bariatric surgery according to the severity of 'periodic binge eating' (CAP) [25]. The answers are in Likert scale, composed of 62 statements grouped into 16 items. Each item contains 3 to 4 statements about behaviors and feelings related to CAP. Each selected statement is applied a score from 0 to 3, ranging from the absence ("0") to the maximum severity ("3") of the CAP. The final score is the result of the sum of the points of each item, which allows the classification of the CAP in: absence of CAP, when the score is ≤17; Moderate CAP, score between 18 and 26; and severe CAP when the sum of the scores is ≥27 [23,24].

2.3.3. Anthropometry and Weight regain

Height (cm) and body mass (Kg) were measured in the preoperative period and 1 (one) year after bariatric surgery. BMI (body mass index) was calculated by dividing body mass by square of height in meters (Kg/m²).

To evaluate weight loss and regained weight after surgery, the equation of %TWL (Percent total weight loss) was used, considered one of the best methods to evaluate post-bariatric weight loss. Studies show that one decade after bariatric there is a physiological weight gain, which can range from 5-10% of %TWL; therefore, weight regain values higher than 15% of NADIR weight (lower body weight achieved after bariatric powders) [26,27] is considered weight regain. It is expected that the nadir will be achieved in the first 12-18 months with loss of at least 20% of the total body weight before performing the surgical procedure [26].

2.3.4. Physical activity

The level of physical activity (PA) was assessed using the summarized version of the International Physical Activity Questionnaire (IPAQ) validated in Brazil by Matsudo et al. [28]. The PA level is classified as vigorous, moderate or mild, according to the time spent by the interviewee in each physical activity. After evaluating the time spent in PA, the individuals are classified as: Sedentary: individuals who do not perform PA for at least 10 minutes continuously during the week. Insufficiently active: individuals who practice PA for at least 10 minutes continuously per week, but insufficiently to be classified as active. Active: individuals who meet the following recommendations: (a) vigorous PA ≥3 days/week and >20 min/session; (b) moderate exercise or walk ≥5 days/week and >30 min/session; (c) any activity >5 days/week and >150 min/week. Very Active: individuals who meet the following recommendations: (a) vigorous AF ≥ 5 days / week and > 30 min / session; (b) vigorous PA ≥3 days/week and >20 min/session and/or 3 to 5 days/week walk for ≥ 30 min/session [28,29].

2.3.5. Anxiety, Stress and Depression

Symptoms of stress, anxiety and depression were measured and differentiated using the Depression, Anxiety and Stress Scale - Short Form (DASS-21) instrument [30]. In this study, the DASS-21 version was used for Brazilian adults translated and valid by Machado and Bandeira [31]. The answers are at a 4-point Likert scale between "0" (does not apply to me) to "3" (it applies a lot to me, or most of the time). Based on the tripartite model, dass-21 groups the symptoms of anxiety and depression into three basic structures. The first, characterized by the presence of negative affect, such as insomnia, discomfort, irritability and depressed mood, which are nonspecific symptoms that are included in both depression and anxiety. The second is defined by the presence of specific symptoms for depression: anhedonia and absence of positive affection. The latter structure refers to the specific symptoms for anxiety: hyperactivity and somatic tension. The result is obtained from the sum of the scores of the 7 items of each of the 3 subscales, being possible to obtain three distinct grades, one for each subscale, in which the minimum score is "0" and the maximum "21". Higher scores indicate more negative affective states [32].

2.3.6. Personality

Pathological personality traits were evaluated using the Personality Inventory for DSM-5 Short Form (PID-5-SF) [30]. It is a self-applicable instrument composed of 100 items extracted from the Personality Inventory for DSM-5 (PID-5) [31], which was reduced and validated by Timm et al. [32] regarding its reliability and efficiency of trait criteria of the alternative model for personality disorders in the DSM-5. Items are evaluated on a Likert scale with scores ranging from "0" (too false or often false) to "3" (true or often true). The scores of the PID-5-SF domains are calculated by adding scores from the three scales that contribute to the evaluation of the pathological personality traits of the hybrid model proposed by the DSM-5 [31,32]. In the present study we used the overall score of each dimension of PID-5.

2.4. *Statistical analysis*

We used descriptive statistics (means and standard deviations) for continuous variables, whereas the frequency distributions (absolute and relative values) were applied for the categorical ones. The t-test for independent samples was chosen for the comparison of ages between the group with and the one without weight regimen. The other categorical variables were compared between patients with and without weight regain and between genders using the chi-square test. When relevant, $p<0.05$ was assumed.

Network analysis was performed to investigate the association between biological and psychosocial variables. Indicators of close association and expected influence were given. Variables with higher expected influence values are more sensitive to change and may act as nodes by linking other pairs of variables in the network.

A variable with a high approximate value will be quickly affected by changes in any part of the network and may affect other parts as well. We used the Fruchterman-Reingold algorithm, i.e. data were represented in a relative space where variables with stronger permanent statistics repel one another and those with less pronounced changes repel each other. The Markov Random Fields in Pairs model was

explored to improve the network accuracy. The algorithm adds a penalty "L1" (regularized neighborhood regression). The value is estimated through a less complete selection and contraction operator (LASSO) that controls the sparse network. By means of the extended Bayesian information criterion (EBIC), we selected the lambda from the regularization parameter. EBIC uses a hyperparameter (y) that determines how much it selects sparse models. We set the value of y to 0.25 (range from 0 to 0.50), which is a better value for exploratory networks, as in the present study. In the network analysis, the regularized lower absolute reduction and selection operator (LASSO) algorithms are applied to obtain the precision matrix, which, when standardized, represents the associations between the variables present in the network. For a better visualization of the weight matrix, the network is represented in a diagram containing the variables (nodes) and the relationships (lines). A regression test was also performed to determine the categorical association between the variables.

The blue color represents positive associations, whereas red shows the negative ones. The thickness and intensity of the colors mean the extent of the associations. The analyzes were performed in the R language with R Studio using the basic packages and qgraph.

2.5. *Ethical aspects*

This study was approved by the Brazil National Board of Research Ethics under the requirement of proper informed consent number 4.067.470.

3. Results

Table 1 shows the sociodemographic characteristics and reported physical activity values of participants with and without weight regain separated by gender.

In the group with weight gain (N=42), most participants were female (N=97), satisfied with their current weight (71.4%), had an income between $ 760 and $ 1,900 (59.5%), had completed high school education (57.1%), and considered themselves physically active (25.6%). Two categories had the same value (28.5%): one and three people living in the household. In the group without weight gain (N=82), most participants were also female, satisfied with their weight (53.6%), lived with up to three people in the house (39.0%), had an income between $ 1,900 and $ 3,800 (41.4%), had completed high school education (65.8%), and considered themselves physically active (74.3%). Only the income variable showed a statistically significant difference between the group with and that without weight gain (x2=13.58; p=0.009).

Table 1. Characteristics of the participants.

Variable	N (%)		N (%)		t ou x²	p-value
	Regain (N=42)		Without regain (N=82)			
	Mas	Fem	Mas	Fem		
Age (years old) M(SD)	35.2(6.05)	38.93(9.96)	40.7(7.93)	39.96(10.46)	-1.13	0.26
Gender	10(100)	32(100)	17(100)	65(100)	0.15	0.69
Satisfaction with current weight						
Dissatisfied	2(20)	10(31.25)	8(47)	30(46.15)	3.64	0.056
Satisfied	8(80)	22(68.75)	9(52.94)	35(53.84)		
People in the house						
1	1(10)	11(34.37)	1(5.88)	14(21.53)	3.37	0.49
2	3(30)	4(12.50)	2(11.76)	15(23.07)		
3	4(40)	8(25)	11(64.70)	21(32.30)		
4	2(20)	5(15.62)	3(17.64)	11(16.92)		
5	-	4(12.50)	-	4(6.15)		
Income						
Up to 380 USD	0	3(9.37)	1(5.88)	1(1.53)	13.58	0.009
380USD to 760USD	1(10)	5(15.62)	1(5.88)	18(27.69)		
760USD to 1900USD	6(60)	19(59.37)	3(17.64)	22(33.84)		
1900USD to 3800USD	2(20)	5(15.62)	10(58.82)	24(36.92)		
Over 3800USD	1(10)	-	2(11.76)	-		
Schooling (in years)						
9	4(40)	14(43.75)	10(58.82)	16(24.61)	1.80	0.40
12	6(70)	18(56.25)	7(41.17)	47(72.30)		
≥16	-	0	-	1(1.53)		
Physical activity						
Inactive	3(30)	13(40.62)	4(23.52)	17(26.15)	2.06	0.15
Active	7(70)	19(59.37)	13(76.47)	48(73.84)		

The main results of the network indicated that weight regain was negatively associated with all items of depression, anxiety and stress, with the items of binge eating, and with the dimensions of the personality questionnaire (negative affectivity -0.182; distancing -0.078; Antagonism -0.107; Disinhibition -0.198 and Psychoticism -0.158). The regain is also associated with having a lower income (-0.292) and having a better schooling (0.255).

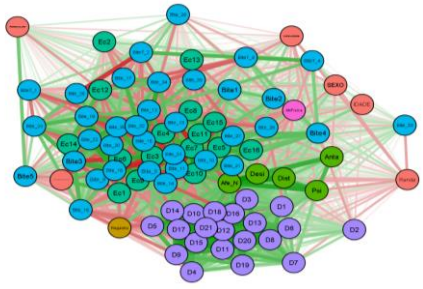


Figure 1. Associations between the variables weight gain, psychological factors (anxiety, stress, depression and personality), sociodemographic and physical activity in bariatric patients.

The regression performed reveals the fit of the model to the data, indicating an explanation of approximately 33.9% in the variability of weight recovery after surgery. The results of the omnibus likelihood ratio test indicate the statistical significance of some predictors. For example, variables such as Detachment, Disinhibition and time since surgery showed statistically significant associations with weight regain as their p-values were below 0.05.

The model coefficients reveal the direction and magnitude of the association between each variable

and weight regain. For example, negative values for certain predictors indicate a possible reduction in the likelihood of weight regain when these factors are present. On the other hand, the results of the assumption verification indicate that the independent variables are not strongly correlated with each other, which suggests that there is no significant multicollinearity in the model.

Additionally, predictive measures provide insight into the model's performance in predicting weight recovery. With an accuracy of 81.9%, the model demonstrates reasonable prediction capacity. The sensitivity of 74% and specificity of 86.4% indicate how well the model can correctly identify true positives and true negatives, respectively.

Figure 2: Cut chart

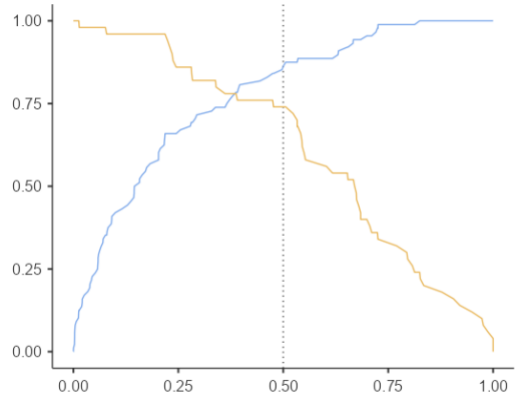
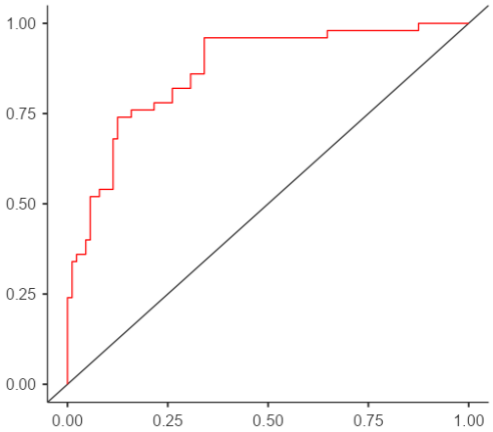


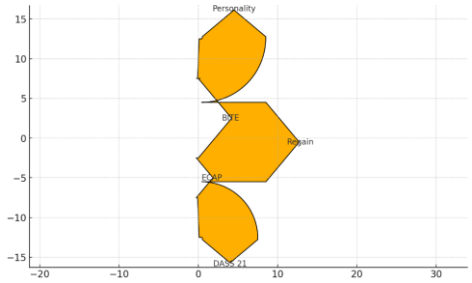
Figure 3: ROC Curve



In short, these statistical data suggest that psychological factors such as Detachment, Disinhibition and time since surgery have a relevant role in weight recovery after bariatric surgery and may be indicative of areas of intervention to reduce the probability of weight recovery in post-bariatric patients surgical.

The main network results showed that regaining weight was negatively associated with all the items regarding depression, anxiety, stress, binge eating, and also with the personality questionnaire dimensions (negative affectivity at -0.182; disengagement at -0.078; antagonism at -0.107; disinhibition at -0.198; and psychoticism at -0.158). Weight regain has also been associated with lower income (-0.292) and better education (0.255).

Figure 4. Associations between the variables weight gain, psychological factors (anxiety, stress, depression and personality), sociodemographic and physical activity in bariatric patients.



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The model coefficients reveal the direction and magnitude of the association between each variable and weight regain. For example, negative values for certain predictors indicate a possible reduction in the likelihood of weight regain when these factors are present. On the other hand, the results of the assumption verification indicate that the independent variables are not strongly correlated with each other, which suggests that there is no significant multicollinearity in the model.

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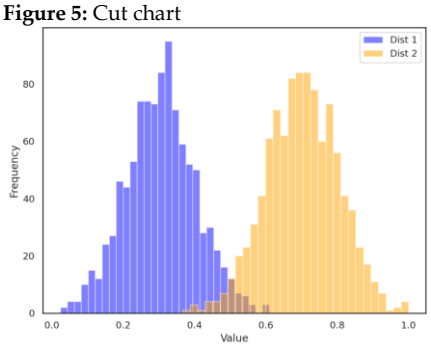
Figure 5: Cut chart



In short, these statistical data suggest that psychological factors such as Detachment, Disinhibition and time since surgery have a relevant role in weight recovery after bariatric surgery and may be indicative of areas of intervention to reduce the probability of weight recovery in post-bariatric patients surgical.

4. Discussion

This study presents the first network evaluation of post-bariatric weight relapse in a CS, including patients that had undergone the surgery 18 to 144 months before. It concomitantly correlates personality aspects, psychological factors such as depression, anxiety and stress, sociodemographic data, physical activity, and eating behavior.

The demographic data analysis revealed that patients with weight relapse had lower income and educational levels. This reality is known in the literature, as higher income denotes more access to health services, healthy food, and multidisciplinary support [31], while higher educational level denotes greater knowledge about health promotion and body care [32].

We have found a negative relationship between weight relapse and personality traits, such as disinterest and negative affectivity (PID-5-SF), high levels of stress, depressive, anxious (DASS 21), bulimic and/or compulsive behaviors (BITE and BES). Therefore, the higher the scores of the mentioned factors, the greater the prevalence of weight relapse.

Longitudinal studies [17, 33, 34] have already demonstrated the importance of psychological factors, such as depression, anxiety, and higher levels of stress in weight relapse in patients undergoing bariatric surgery. However, the literature is still scarce on the impact of changes in post-bariatric eating behavior [15, 17] and personality [16] on weight regain.

Our hypothesis is that these negative personality traits drive compensatory behaviors, such as binge eating episodes, in a population that is more likely to suffer relapse, such as patients undergoing bariatric surgery. In this context, binge eating prevalence in patients after bariatric surgery varies between 16 [35] and 49% [36]. Yet, lower levels of physical activity were negatively associated with personality traits such as psychoticism, detachment, and disorders (BED). Furthermore, patients with BED were more satisfied with their body weight.

Considering that the practice of physical activity, regardless of the type, occurs in places visited by different people, it is more likely that the unusual behavior of people with psychoticism and detachment, such as hostility and avoidance of personal proximity, intimacy, respectively, would explain this relationship [37]. In addition, it is known that eating disorders can cause a false sense of self-control, self-image [38, 39], low emotional regulation, and a significant increase in depressive symptoms [40], which associated with compensatory behaviors and lack of physical exercise increases weight relapse.

In patients from 18 to 144 months of follow-up, this study results showed how anxiety, depression and stress act in network with sociodemographic factors, binge eating and decrease in physical activity scores, culminating in weight relapse. A study published in 2019 using network analysis identified the importance of personality traits and anxiety symptoms in bariatric patients. However, the short follow-up period of the individuals (nine months) and the non-inclusion of depressive symptoms in its analysis were limitations [16]. We believe that the analysis of depressive symptoms in the network approach is fundamental when it comes to weight relapse, since depression was observed as the most prevalent item in weight regain and due to its association with compulsive behaviors [34, 37].

We were also able to predict the most susceptible factors to health interventions by means of the network analysis. In our study, the following stood out: personality traits (disinterest and negative affectivity); and high depression, anxiety, and stress scores. Our data are in line with the literature, which defines mood and anxiety disorders as an important barrier for weight maintenance in patients after bariatric surgery [35, 36, 41]. Nevertheless, information on the influence of aspects inherent to personality [16] is an unprecedented outcome. This fact is important, given that the way how risk factors interact in patients who have regained weight after bariatric surgery has not been fully mapped yet [17, 23], and is currently seen as a multifactorial system [31, 42]. Thus, by delimiting the most susceptible factors to change, we are creating subsidies to reflect on health promotion models in this population.

This study marks a pioneering endeavor in comprehensively examining post-bariatric weight relapse through the lens of complex systems, linking it to personality attributes, psychological aspects, sociodemographic features, and behaviors. The insights unveiled a clear association between weight relapse and lower income and educational levels, reflecting the critical role socioeconomic status plays in accessing health resources and fostering a robust understanding of body care. The negative correlation between weight relapse and personality traits, psychological stress, depressive, anxious, and bulimic behaviors accentuate the intricate interplay among these elements, underscoring their pivotal roles in driving weight regain post-bariatric surgery.

Unraveling the complex web of factors influencing weight relapse, our findings underscored the significance of negative personality traits and psychological distress, aligning with existing literature that highlights their profound impact on weight

maintenance post-surgery. The heightened prevalence of binge eating episodes and their correlation with certain personality traits further elucidates the compensatory behaviors triggering relapse, underscoring the intricate relationship between psychological attributes and weight management. Additionally, the negative association between lower physical activity levels and specific personality traits like psychoticism and detachment, coupled with the satisfaction with body weight among patients with binge eating disorders, signals the intricate interweaving of psychological elements, eating behaviors, and physical activity in the context of weight relapse.

While shedding light on the intricate nexus of factors contributing to weight regain post-bariatric surgery, this study's insights extend beyond established findings, emphasizing the critical role of depressive symptoms and the intertwined nature of personality traits and psychological distress. Recognizing these factors as pivotal to health interventions, our analysis indicates a need for tailored approaches targeting these specific domains to curtail weight relapse effectively. However, inherent limitations, including the study's cross-sectional design, a relatively small sample, and its single-center focus, temper the generalizability of these findings, emphasizing the need for further longitudinal investigations encompassing diverse populations and settings.

The limitations of the present study include limitations inherent to cross-sectional studies, small sample, and performance in only one medical center.

5. Conclusion

Therefore, the present study provided a new approach to evaluate interactions in weight relapse and correlates it as a complex adaptive system. Depressive, anxious and compulsive behaviors, high levels of stress and personality traits, such as disinterest and negative affectivity, are the variables that most influenced weight regain in patients undergoing bariatric surgery.

The centrality indicators also allowed us to assess which variables are most sensitive to the intervention and those which will most quickly receive the intervention effect. In this case, we highlighted the personality traits (disinterest and negative affectivity) and high scores of depression, anxiety and stress. Thus, these data can support public policies in order to promote mental health for this population. Finally, longitudinal and multicenter studies are needed to better assess this issue.

Conflicts of Interest: The authors declare no conflict of interest.

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