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Mediating role of exercise in the relationship between body dissatisfaction and overeating using structural equation modeling

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Abstract

Background With the rapid development of society, teenagers have more access to individuals with perfect bodies and are becoming more concerned about their body image. Currently, few studies assess body image and eating disorders comprehensively in China. Given the seriousness of these issues, there is an urgent need to understand the current state of body image and eating behaviors among Chinese people and formulate preventive strategies.

Methods In this study, 1711 college students between 17 and 23 years old in southern China completed relevant anthropometric measurements, essential information and three questionnaires. Multiple linear regression was used to screen the variables, and sex invariant analysis was used to determine whether to separate men and women to fit the structural equation model. Finally, the path diagram of the structural equation model was used to explore the complex relationship between body dissatisfaction and overeating.

Results Our results found that 69.4% of participants with a body mass index (BMI) within the normal range were dissatisfied with their weight. Further, body dissatisfaction directly or indirectly leads to overeating. Additionally, exercise played a mediating role in the body dissatisfaction and overeating of college students.

Conclusions If BMI directs body dissatisfaction, it may lead to overeating. As a mediating factor in structural equation modelling, exercise may provide strategies to reduce body dissatisfaction and prevent overeating.

Keywords Body image, Body dissatisfaction, Eating disorders, Overeating, Structural equation modelling, College students

Background

Eating disorders are very serious mental disorders [1]. Among the manifestations are overeating and obesity [2], as well as serious damage to physical and mental health, which plays a decisive role in disturbing attitudes towards eating, weight and body image [3]. Eating disorders have become an important public health issue and have attracted considerable attention, as their incidence has gradually increased in recent years [4]. Adolescent boys and girls are at high risk for eating disorders [5]. Given the worldwide prevalence and high risk of [6], timely identification and prevention are especially important.

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Introduction

Overeating, which is a major manifestation of eating disorders, has complex cause. A study of 4,746 adolescents in the United States showed that approximately 25 per cent of them engaged in overeating behavior [7]. Chinese teenagers, influenced by American culture and media, also refer to American eating habits, and the trend is spreading [8]. Research suggests that "food addiction" is a major motivator for overeating [9], in turn, depends on multidimensional factors: restrict eating, emotional eating, extra eating [10]. The immediate effect of overeating is weight gain and there are 2.1 billion overweight and obese people in the world [8]. Past research has focused on the relationship between obesity people and overeating; however, few studies have addressed the relationship between psychological and behavioral aspects of overeating behaviors in the general population.

There is strong evidence that dissatisfaction with one's body image is an important manifestation of eating disorders [11]. With the rapid development of society, teenagers have more access to people with ideal bodies and are becoming increasingly concerned about their body image [12]. Body image depends on multiple dimensions, most notably, self-perceptions about weight, body dissatisfaction, mental health, and exercise [13, 14]. In the general population, discrepancies between body weight and ideal body size are a direct result of body dissatisfaction. Among adolescents, nearly one in two males and one in three females have some degree of self-reported body dissatisfaction [15]. Body dissatisfaction and eating disorders reflect psychological and sociocultural interactions [16]. An important factor driving this development is the internalization of the "thin ideal" [17], Women like to be slimmer and find it more attractive [18]. However, men's body dissatisfaction manifests itself differently from that of women, with men favoring a powerful muscular body. A recent study found that Chinese social media stigmatizes very thin men as "xigou"(A Chinese greyhound with a very thin body and thin limbs.) [19]. Most of these studies referred primarily to Western cultures and populations [20], with less research on body dissatisfaction and eating disorders in China, there is a great need to fill this gap.

In addition, eating disorders can affect a person's psychological condition and even cause depression [21, 22]. Several studies have shown that eating disorders and depression are the most common comorbidities [23]. According to the WHO, approximately 350 million people worldwide suffer from depression [24]. A 1987 study of adolescents found an 8 per cent prevalence of mental disorders and depression [25]. By 2021, a cohort study showed a 25 per cent prevalence of depression among adolescents [26]. Depression is recurring, disabling, long-lasting and difficult to cure once it emerge [27]. Given the rising incidence of depression and the enormous burden and harm caused by eating disorders, it is important to understand, recognize and try to find effective solutions [1, 28].

The vast majority of the above studies on eating disorders and body image have been conducted using correlation analysis, analysis of variance, logistic regression, and linear regression, with independent and dependent variables artificially determined in advance, purely for descriptive purposes and without causal assumptions, often ignoring indirect effects between variables. When studying the quantitative aspects of behavioral psychology, variables are difficult to measure, and the results obtained by ignoring these issues may be relatively inaccurate. Structural equation modelling, on the other hand, does not pre-determine the independent and dependent variables and is better able to examine how multiple difficult-to-measure variables are related and to identify direct and mediated links between variables [29].

There is limited literature on body image and eating disorders in China, especially on the topics of self-perception of body index (body dissatisfaction) and the structural role of depression on overeating. Therefore, we aimed to use structural equation modelling to explore the relationship between the dimensions of body image (body index, body dissatisfaction, depression, exercise) and one of the main manifestations of eating disorders (overeating), and to try to find ways to alleviate overeating. To promote a clearer understanding of Chinese adolescents' body image and eating disorders, make certain changes in their eating behaviors, and have healthier living and eating habits.

Materials and methods

Study design

Participants were recruited via convenience sampling, focusing on college students who voluntarily filled out a detailed questionnaire in Chinese. Dietary behaviors were quantified using CFA, subsequent analyses were performed employing multiple linear regression and structural equation modeling to explore the relationship between dietary behaviors and lifestyle habits, emotional state, body dissatisfaction.

Study sample size

Sample-size determination was calculated with the use of G*Power 3.1.9.7 software, with four predictors, 95% power, and a significance level of 0.05, and a minimum of 652 participants were required to detect small effects (f^2= 0.02) in a multiple linear regression. The importance of sample size in modeling and confirmatory factor analysis (CFA) studies was emphasized by different investigators, who agreed that a minimum of 200 participants was required for structural equation modeling (SEM) studies

[30]. The gender invariance analysis we used was a special case of CFA, and given that CFA is a type of SEM, a larger sample size of 300 students was considered appropriate to use CFA to achieve the study objectives. The model in this study was not complicated, with only 33 observed variables. Therefore, we used the N: q rule proposed by Eicher Sabah et al. [30], to estimate the number of parameters with a 10:1 sample size ratio under SEM, and the minimum sample size required was 330. Finally, 1711 participants were included in our statistical analysis, so our sample size was adequate.

Study design and participants

Our study used a cross-sectional design. A comprehensive university in southern China was selected to recruit respondents through publicity. The survey was conducted for 1 month. We conducted the survey by convenience sampling method. After each survey, we recorded the classroom number to prevent the next repeated survey. Moreover, each time students participated in the evening study, we randomly selected a classroom to conduct the survey and recruited participants through the publicity of the study room. We would explain that no data breach involved in our findings and that the findings are only for scientific research. If there was any discomfort during the survey, students were allowed to withdraw. We also surveyed students who did not attend evening study by visiting each student's dormitory.

Before the survey began, the investigators were given standardized training. The survey was conducted by distributing a questionnaire that declared the content and purpose of the study on the first page when students were attending evening study sessions. The survey was conducted after obtaining students' consent through a signed informed consent form. The inclusion criteria for the project were full-time college students with household registration in southern China. More than 1900 participants were recruited, all of whom completed the measurements and questionnaires. The participants who did not sign the informed consent form were excluded from the final analysis. Owing to the small number of students under the age of 16 and over the age of 24, these participants were also excluded from the study. Of these, 1711 (931; men and 780 women) with complete information were included in the analyses.

Measurements

Height was measured with a portable rangefinder (Seca 213, Germany) with an accuracy of 0.1 cm. Body weight (precision 0.1 kg), fat percentage, and muscle mass (precision 0.1 kg) were measured using a body composition meter (BC-610, Japan). These instruments are often used in scientific research because of their high precision and accuracy, and have been widely recognized and applied in the world. Body mass index(BMI) was calculated based on height and weight. Experienced personnel recorded the measurements.

Body dissatisfaction

Finally, the ideal BMI was calculated based on the actual height and ideal weight provided by the participants. Further, the ideal BMI was subtracted from the actual BMI to obtain the body dissatisfaction score [31]. The formula is as follows [18, 32]:

Body dissatisfaction = actual BMI - ideal BMI.

Questionnaire content

The questionnaire included students' age, fat percentage, muscle mass, gender (men; women), height, weight, ideal weight, and other basic information: grade, major, only child (yes; no), and average monthly cost of living, as well as three scales measuring exercise level, emotional state, and eating behavior.

Criteria for division

Physical activity rating Scale-3

The Physical Activity Rating Scale (PARS-3) was developed by Takao Hashimoto, a Japanese scholar, and revised by Liang et al. [33]. This scale examines the amount of physical activity, including intensity, frequency, and exercise duration. It uses them to measure the level of participation in physical activity. The PARS-3 scale included three dimensions: intensity, frequency and duration. Physical activity level = intensity x duration x frequency. Intensity and frequency were graded from 1 to 5 points and scored as 1 to 5 points, respectively. Simultaneously, time was graded from 1 to 5 points and scored from 0 to 4. The highest score is 100 points, and the lowest score is 0 points. Physical activity level assessment criteria: ≤19 was defined as fluctuating activity level; 20–42 was defined as moderate activity level; High activity level was defined as ≥43. In the exercise intensity dimension, the question is, "How often do you exercise?", answer Number 1 indicates "minimum intensity," Number 2 indicates "low intensity," Number 3 indicates "medium intensity," Number 4 indicates "high intensity," and Number 5 indicates "maximum intensity." In the "frequency" dimension, the question is, how many times a month do you engage in the above-mentioned physical activities? Response number 1 represents "less than once a month", number 2 represents "3 to 5 times a week", Number 3 represents "2 to 3 times a month", Number 4 represents "approximately once a day." Number 5 represents "1 to 2 times a week". In the duration dimension, the question is, how many minutes at a time do you engage in the above intensity of physical activity? Response numbers 0 indicated "less than once a month", 1 indicated "3 to 5 times a week", 2 indicated "2 to 3 times a month", 3 indicated

"approximately once a day", and 4 indicated "1 to 2 times a week". The pars-3 results represent the amount of physical activity of the study subjects [34].

Self-depression scale

Self-Depression Scale (SDS) was developed by W.K. Zung in 1965 and has been widely used in emotional state assessment and investigation. The Cronbach's alpha of most researchers for SDS scale was between 0.68 and 0.79 [35]. The total SDS score was the sum of the 20 entry scores (raw score X), and the raw score was converted to a standardized score (indicator score: Y), Y = (1.25X). For example, here are the top 5 questions on the SDS questionnaire: (1) I feel depressed and depressed. (2) I feel at my best in the morning. (3) I want to cry or want to cry. (4) I don't sleep well at night. (5) I eat as much as usual. Entries 1, 3, 4, 7, 8, 9, 10, 13, 15, and 19 are positive scores, with options A, B, C, and D scoring 1, 2, 3, and 4, respectively. Entries 2, 5, 6, 11, 12, 14, 16, 17, 18, and 20 were scored negatively and assigned 4, 3, 2, and 1 points, respectively. Depression judgement criteria: not depressed: <53 points, depressed: ≥53 points [36]. Finally, the Cronbach's alpha coefficient obtained by the reliability analysis of SPSS26.0 was 0.79, indicating that SDS was feasible in our study subjects.

Chinese version of the Dutch Dietary Behavior Questionnaire

Ya-Fen Wang modified the Chinese version of Dutch Dietary Behavior Questionnaire(C-DEBQ) to measure dietary behavior in China. The Cronbach's alpha coefficient was 0.94 [10]. The C-DEBQ consists of 33 questions divided into 3 dimensions to assess adolescents' emotional, external, and restrained eating styles. Emotional eating consists of 13 questions, such as "When you are angry, do you have a desire to eat?" There are 10 questions about external eating behaviors, such as "Do you eat more than usual when you see other people eating?" There are 10 questions about eating in moderation, such as, "Do you find it difficult to resist tasty food?" Scores range from 1 (never) to 5 (always) and from low to high. Higher scores indicate a greater the degree of specific dietary tendencies. The total score for the three dimensions is 165, which was used to assess the tendency to overeating [37]. According to Aiche Sabah and colleagues, the C-DEBQ of this study has good psychometric properties [38]. In confirmatory factor analysis, chi-square/df=4.232, Standardized Root Mean Square Residual (SRMR)=0.078, comparative fit index (CFI)=0.909, root mean square of the error of approximation (RMSEA)=0.068 for men, chi-square/df=3.614, SRMR=0.074, CFI=0.903, RMSEA=0.065 for women. Finally, the Cronbach's alpha coefficient obtained by the reliability analysis of SPSS Windows software version 26.0 was 0.95. Thus, this indicates that C-DEBQ was feasible for our study participants.

Statistical methods

All variables were first examined for descriptive statistics, including mean, standard deviation, skewness, and kurtosis. A non-parametric test was used to analyze gender differences in BMI, fat percentage, ideal BMI, body dissatisfaction, muscle mass, SDS score, physical activity score, and three eating behaviors. Differences between genders were analyzed using chi-square tests for body type typing, physical activity levels, and depressive symptoms. Multiple linear regression analyses were used, with stepwise method for variable selection, mixed for direction selection, and threshold p set at 0.20. They tested the model's fit by R^2 and root mean square error (RMSE), with the variables (percentage of fat, body dissatisfaction, exercise, and SDS scores) selected as predictor variables and overeating as dependent variable. Additionally, to decide whether to separate men and women in the structural equation model, model estimation was based on maximum likelihood with robust standard errors (MLR) to account for slight deviations from normality. We used several fit indices to test the fit of the data model: (i) chi-squared /df≤3 indicates an acceptable fit, whereas ≤5 indicates a reasonable fit; (ii) Fit index (CFI)>0.95 was considered satisfactory, and values between 0.90 and 0.95 were considered acceptable; (iii) Root mean square Error of Approximation (RMSEA), the range of 0.05–0.08 indicates a sufficient fit; (iv) Standardized root mean square residual (SRMR), values<0.05 indicate a good fit and a range between 0.05 and 0.10 is acceptable [30, 39–41]. Separate CFAs for each measure were first performed to examine model fit for both men and women. According to the previous guidelines, measurement invariance was established when ΔCF≤0.01 and ΔRMSEA≤0.015 [42, 43].

Subsequently, we conducted structural equation modelling using multivariate analysis. The selected predictor variables and the original variable (body mass index) for body image were included in a structural equation model to test the relationship between body image and overeating and observe the mediating effects. The model's fit was tested by observing the comparative fit index (CFI) and the root mean square of the error of approximation (RMSEA). The relationship between any two variables was tested, and the degree of fit of the overall model was observed. In addition, we observed the mediating effects between BMI, exercise, depression, overeating, and body dissatisfaction. Finally, Tukey's test was used to examine the difference between the means of the overeating scores of students with three different levels of exercise and to observe the degree of dispersion through the standard deviation of the forward error bars. All differences

Table 1 Basic characteristics of participants ($n=1711$)

	Mean ± SD or *n*(%)			*p*
	Men($n=931$)	Women($n=780$)	Total(1711)	
BMI(kg/m2)	22.2 ± 3.7	21.2 ± 3.0	21.8 ± 3.4	<0.01
Fat%	16.4 ± 7.4	27.3 ± 6.3	21.4 ± 8.8	<0.01
Ideal BMI(kg/m2)	21.3 ± 1.9	19.1 ± 1.8	20.3 ± 2.1	<0.01
Body dissatisfaction(kg/m2)	1.0 ± 3.2	2.1 ± 2.3	1.5 ± 2.9	<0.01
Muscle mass(kg)	51.1 ± 7.7	36.4 ± 4.6	4.4 ± 9.8	<0.01
SDS score	44.9 ± 9.8	46.8 ± 8.9	45.8 ± 9.4	<0.01
Physical activity score	22.3 ± 21.5	11.5 ± 14.8	17.4 ± 19.5	<0.01
SDS category				
Depression	183(19.7)	185(23.7)	368(21.5)	<0.05
No depression	748(80.3)	595(76.3)	1343(78.5)	
BMI category				
Underweight	87(9.3)	82(10.5)	169(9.9)	<0.01
Normal	599(64.3)	588(75.4)	1187(69.4)	
Overweight & Obesity	245(26.3)	120(15.4)	365(21.3)	
Activity level category				
Low exercise	561(60.3)	659(84.5)	1220(71.3)	<0.01
Medium exercise	203(21.8)	74(9.5)	277(16.2)	
High exercise	167(17.9)	47(6.0)	214(12.5)	
Eating behavior				
Restrained eating score	24.6 ± 8.1	28.5 ± 7.5	26.3 ± 8.0	<0.01
Emotional eating score	23.8 ± 10.0	26.7 ± 10.0	25.1 ± 10.1	<0.01
External eating score	31.0 ± 8.1	35.8 ± 7.1	33.2 ± 8.0	<0.01
Overeating	79.6 ± 19.6	90.5 ± 18.2	84.6 ± 19.7	<0.01

BMI: body mass index, SDS: Self-Depression Scale

were statistically significant ($p<0.05$). SPSS Windows software version 26.0, Amos version 24.0, and JMP16.0 were used for statistical analysis.

Results

To ensure the normality of the distribution, we calculated skewness and kurtosis, with skewness values ranging from −0.134 to 1.402 (i.e. absolute skewness values < 2) and kurtosis values ranging from −0.323 to 1.882 (i.e. absolute kurtosis values < 2). According to Aiche Sabah et al., our skewness, as well as kurtosis, were within the acceptable range [39, 42].

The participants' basic characteristics are listed in Table 1. The age of the participants ranged from 17 to 23 years old, with a mean age and standard deviation of 19.5 ± 1.9. There were 931 male students and 780 female participants. Of the students, 71.3% exercised at low intensity, 16.2% exercised at moderate intensity, and just 12.5% exercised at high intensity. Male students had higher mean BMI, ideal BMI, muscle mass, and exercise scores than female students; however, female students had higher mean fat percentage, body dissatisfaction, and SDS scores than male students (Table 1). In the eating behavior scores, the overall mean overeating score was high for all students, and the mean scores for restrictive eating, emotional eating, and extra eating were greater for women than for wen ($p<0.01$).

Table 2 Factors leading to overeating among university students

	β	t	VIF	*P*
Fat%	0.69	10.9	1.7	<0.001
Body dissatisfaction	0.83	4.39	1.63	<0.001
Physical activity score	-0.11	-4.6	1.14	<0.001
SDS score	0.1	2.25	1.01	0.025

SDS: Self-Depression Scale VIF variance inflation factor

R^2:0.2; Root Mean Square Error (RMSE):19.6

Table 2 shows the results of the multiple linear regression analyses of diets affecting overeating. The results showed percentage fat (β = 0.69, $p<0.001$), body dissatisfaction (β = 0.83, $p<0.001$), physical activity (β = -0.11, $p<0.001$), and SDS (β = 0.1, $p=0.025$) were significant predictors of overeating.

A sex invariance analysis was performed before analyzing the structural equations to decide whether both men and women could be included in one analysis. The results in Table 3 shows all fit indices were outside the acceptable model fit range for both men and women. The sex invariance of the model was supported when the difference in CFI, RMSEA (that is, ΔCFI, ΔRMSEA) between nested models for every two comparisons was less than 0.01 [42].

Table 4 shows the direct and indirect and total effects between body dissatisfaction and overeating. The results

Table 3 Measurement invariance of the C-DEBQ scale across sexes

	Men	Women	Men vs. Women
χ^2/df(Δχ2/df)	4.232	3.614	0.618
P	<0.001	<0.001	<0.001
CFI(ΔCFI)	0.909	0.903	0.006
RMSEA (ΔRMSEA)	0.068	0.065	0.003

CFI = comparative fit index; RMSEA = root mean square error of approximation

Table 4 Direct and indirect relationships between two variables

Effect	Path	β	SE	*P*
Direct effect	BD→Overeating	0.54	0.08	<0.01
Indirect effect	BD→PA→Overeating	0.12	0.02	<0.01
Total effect	BD→Overeating	0.66	0.08	<0.01

BD: Body dissatisfaction; PA: Physical activity

showed that exercise had a partial mediating effect on the relationship between physical dissatisfaction and overeating ($p<0.001$).

Figure 1 demonstrates the structural equation modelling incorporating BMI, exercise, body dissatisfaction, SDS, overeating, and its two dimensions (emotional eating and restrictive eating), while excluding percentage fat from the model. The path diagram of structural equation modelling shows that body dissatisfaction mediates the relationships between BMI and exercise, BMI and overeating, SDS and exercise, and SDS and overeating simultaneously. In addition, exercise was the mediating effector between body dissatisfaction and overeating. However, the remaining mediating effects were not significant and did not change significantly (retaining two decimal places resulted in unchanged values). The model fit indices showed that the structural equation model was acceptable (AICC = 80321, BIC = 80435, CFI = 0.9, RMSEA = 0.1, SRME = 0.08, $P<0.001$).

Figure 2 shows that all students had higher overeating scores in the low- and moderate-exercise groups than in the high-exercise group ($p<0.001$), whereas there was no significant difference between the moderate- and high-exercise groups.

Figure 3 shows that binge drinking scores were higher among men in the low exercise group than in the high exercise group ($p=0.008$), while there were no significant differences between the other groups.

Discussion

This study investigated body image and eating behaviors among university students in southern China and explored ways to alleviate eating disorders. To investigate the complex relationship between one of the main manifestations of eating disorders (overeating) and multiple dimensions of body image. We conducted a two-stage analysis to explore the relationship between body image and overeating by first screening the predictor variables of overeating through multiple linear regression and then fitting the structure between the initially screened variables, as well as BMI, through structural equation modelling.

We included body image as a factor to explore overeating by assessing body image comprehensively across four metrics: body mass index (BMI), self-perception of BMI, and psychological and behavioral factors. We found that both BMI and depression are positively related to overeating indirectly through body dissatisfaction, and that body dissatisfaction is directly positively related to overeating (Fig. 1). Our results show that men have a higher ideal BMI than women and lower body dissatisfaction scores than women (Table 1). This reflects men's desire to have a more toned body, whereas women want a slimmer body [44, 45]. In other words, body dissatisfaction in men is mainly an upward body image comparison oriented towards strong muscles, whereas in women it is mainly a downward body image comparison oriented towards thinness; the intensity of this comparison is more severe

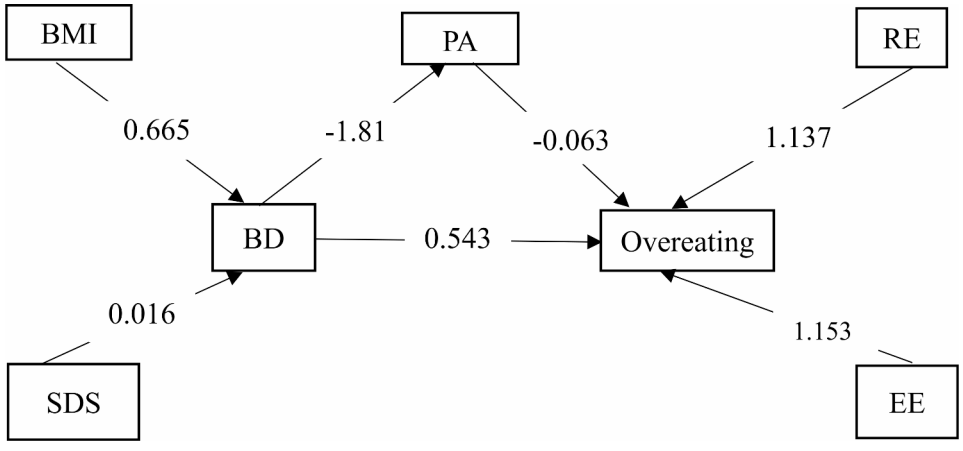

Fig. 1 Structural equation modelling between BMI, exercise, body dissatisfaction, SDS, and overeating. BMI: Body mass index PA: Physical activity RE: Restrained eating. BD: Body dissatisfaction SDS: Self-Depression Scale score EE: Emotional eating

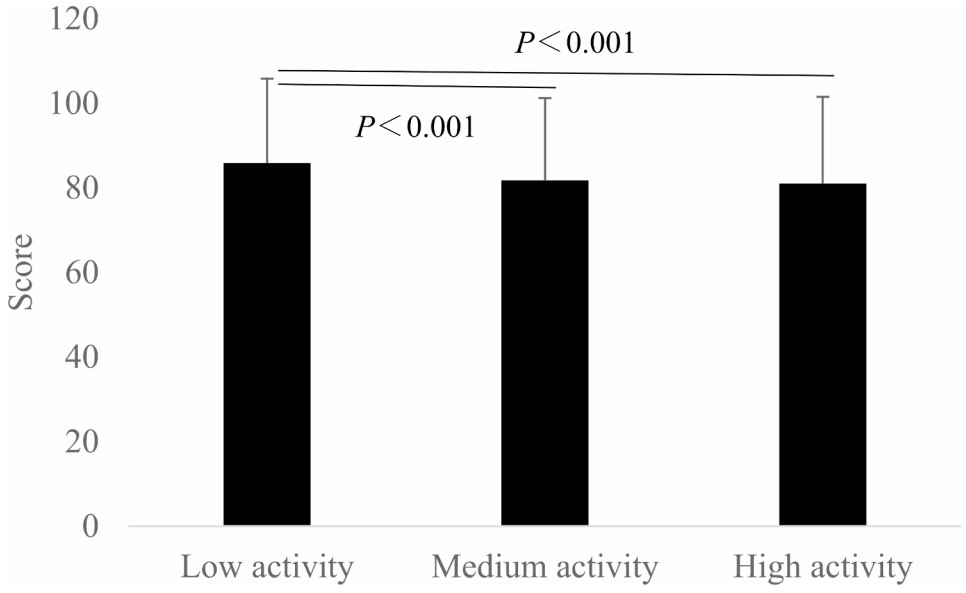

Fig. 2 Overeating among college students in different exercise type groups

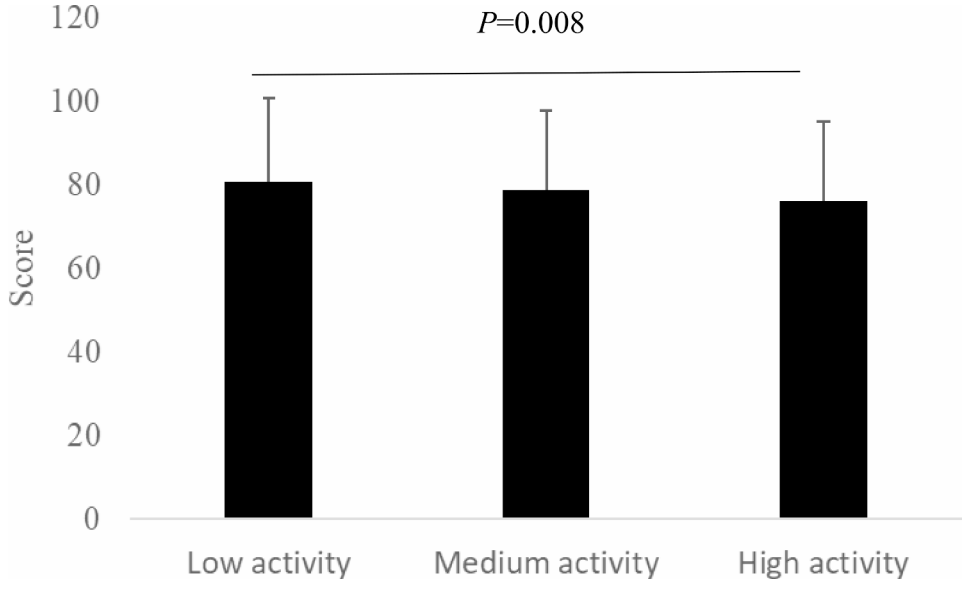

Fig. 3 Overeating among male university students in different exercise type groups

in women than in men. To achieve their goals, women usually diet to lose weight [46]. The long-term restriction of food intake is often unsustainable, it can eventually lead to uncontrolled eating due to internal or external stimuli and retaliatory eating [47]. To achieve a toned body, man usually perform physical exercise [48]. However, a muscular body requires a longer time to build and is often difficult to achieve [32]. In contrast, the feeling of hunger after sudden and strenuous exercise promotes eating behaviors [49]. In short, men's irrational short bursts of strenuous exercise and women's extreme dieting do not meet their needs; instead this body dissatisfaction is likely to act as a risk factor for future overeating.

However, the body dissatisfaction we investigated was largely based on self-rating of BMI. In our survey results, the overall BMI levels of the students were within the normal range. In contrast, most recent U.S. and Canadian surveys of body dissatisfaction show that the obesity rate in their countries is relatively high [50, 51]. Their body dissatisfaction is mainly aimed at shifting from obese to normal, whereas our students' body dissatisfaction concerned shifting from normal to unhealthily slim or more muscular and strong. This is because unlike the culture and perceptions in the United States and Canada, Chinese social media creates more body image anxiety and peer pressure, which makes adolescents have unhealthy

aesthetics [52, 53]. In addition, owing to social media campaigns, women with slimmer bodies are considered more attractive [54]. Rapid economic growth has also provided people with greater access to influential people's idealized and frequently edited photographs [55]. These findings demonstrate the particular importance of specific cultural factors in influencing eating and body image, that is, the sociocultural facilitation of body-ideal differences, by which Chinese adolescents may internalize and compare themselves to local and Western perfect ideal body builders. In short, our findings provide evidence that sociocultural influences are an important factor in the triadic influence model of body image and eating disorders [56]. Therefore, the culture of different countries is important in shaping people's perceptions of their body image. In conclusion, body dissatisfaction is largely due to people's comparisons and internalization. Second, the effects of differences between local and Western cultures on body imagery should be directly examined in future research.

Another unexpected path from our results is that depression may exacerbate overeating behavior through body dissatisfaction (Fig. 1). A study of more than 13,000 college students in southern China showed that depression was associated with the formation of self-awareness in early adulthood [57]. A prospective study in the UK also stated that as depressive symptoms worsened, the body dissatisfaction index increased [58]. These studies validate our results. Depression manifests as impaired social skills, low mood, eating disorders [24]. However, socially dysfunctional individuals tend to have low self-esteem and are dissatisfied with their bodies [59]. In addition, the factors responsible for depression overlapped significantly with emotional eating disorders, with emotional eating being the strongest predictive variable in our structural equation modelling. However, for the relationship between depression and body dissatisfaction, we observed very small effect sizes in our structural equation modelling, potentially due to the fact that participants with normal BMI nevertheless had higher body dissatisfaction identification with themselves. In contrast, since the onset of COVID-19, there has been a significant increase in eating disorders and the prevalence of depression in several regions [60]. Thus, without changing college students' body dissatisfaction perceptions, there is a high likelihood of a shift to larger population-level effects.

As seen in our structural equation modelling, there is a very weak negative correlation between exercise dose and overeating (Fig. 1). One systematic review of exercise and eating behavior concluded that overeating does not affect exercise [61], which is slightly different from the results of our study. Based on our results alone, it appears that those with a tendency to binge eat reduced their desire to exercise, but one cannot rule out the reason that the overall lower levels of exercise in our sample led to a tendency to overeating instead. It is worth noting from the Tukey test that overeating scores for medium- and high-intensity exercise were significant in comparison to low intensity in all students, and high intensity was significant in comparison to low intensity in males alone, whereas this was not observed in women (Figs. 2 and 3). Overall, exercise may be compensated for by greater energy intake and increased appetite [62]. Men, on the other hand, need stronger stimulation to trigger this mechanism. Women cannot exclude the possibility that they normally exercise less or are unable to accurately describe their exercise profiles to cause this phenomenon. Therefore, future studies need to strengthen the distinctions in the links between exercise and overeating across genders.

In our mediation analyses, the model alone showed that college students' body dissatisfaction led to avoidance of physical activity (Fig. 1). It has been suggested that those with high levels of body dissatisfaction avoid playing sports in public, which they find embarrassing [63]. This is a sign of low self-esteem and a lack of self-confidence. People with this mentality tend to eat out of inner loneliness, which leads to eating disorders [64]. Conversely, exercise explained the association between BMI, depression-oriented body dissatisfaction, and overeating among college students, significantly mediating the likelihood of controlling overeating. Earlier, we argued that dieting in girls and brief periods of vigorous exercise in boys do not change body dissatisfaction, but instead may predict future overeating. Among all students, higher-intensity exercise was significant in reducing overeating relative to lower-intensity exercise, suggesting that we should consider adhering to long-term moderate-intensity exercise to reduce body dissatisfaction and prevent the onset of overeating. However, in our survey, up to 71.3% of the students lacked physical activity. This phenomenon is also common in southern China. A study that surveyed 650 college students in Guangzhou, China also found that nearly half lacked physical activity [65]. Despite our findings on the importance of exercise in preventing overeating, the fact that low levels of exercise were found in the Chinese university student population suggests that more specific initiatives should be implemented to increase exercise levels. Therefore, quantitative and specific exercise modalities should be considered in future studies to examine potentially important correlates of risk and maintenance factors.

Implications

This study advances the theoretical framework surrounding body dissatisfaction, exercise, and eating behaviors. Our research extends the literature by investigating the moderating influence of exercise on the link between

body dissatisfaction and overeating, a relationship that has been inadequately explored within Chinese academic research. Utilizing structural equation modeling, we unveil the intricate dynamics among depression, exercise, body dissatisfaction, and overeating, positing exercise as a potential mediator—a novel contribution to the field. The study's findings substantiate the multifaceted role of exercise in fostering and mediating healthful lifestyles among college students, a demographic of significant interest given the rising incidence of body image concerns and eating disorders in this population.

Our study has some practical implications, confirming a significant positive association between body dissatisfaction and overeating behavior in college students. This finding underscores the intricate relationship between students' body image perceptions and their eating habits. By identifying exercise as a critical mediating factor, our study provides a foundation for the development of tailored interventions aimed at reducing the negative impact of body dissatisfaction on eating behaviors. Notably, our analysis did not detect significant differences between male and female participants. This suggests that the psychological and behavioral mechanisms linking body dissatisfaction to overeating may be similarly manifested across genders, which has critical implications for the universal application of preventive measures and health initiatives.

Limitations and strengths

Our study used confirmatory factor analysis, gender invariance analysis and structural equation modeling (SEM) to explore the complex relationship among body dissatisfaction, exercise and overeating. The findings provide evidence for future interventions.

The population selected for this study only included 1,711 students between the ages of 17 and 23 in southern China. Despite the high adherence rate among students, the sample size was still small and the sample only included college students, thus not allowing the conclusions to be extrapolated to the entire Chinese population. Therefore, future research should replicate this study with a larger group of participants to ensure the robustness and generalizability of the findings. Second, body dissatisfaction was evaluated by the actual BMI and ideal BMI. Given that ideal body weight is derived from the participant's estimate, results for individuals who are not sensitive to body weight may not be accurate. However, compared with the sex-adapted silhouettes method commonly used in Europe and the United States (the ideal body shape and the actual body shape are based on subjective judgment), this method can better reflect the body dissatisfaction of Chinese people who are relatively sensitive to weight. our research on this methodology is still underway, and its superiority is unclear at this time. In the future, we intend to strengthen our research on this methodology. In addition, this was a cross-sectional study, and causal inferences could not be made. We plan to build a cohort to address this gap in future studies. Finally, our exercise can't be accurately quantified, in the future, quantitatively analyzing exercise will help us provide more accurate strategies and exercise norms to reduce body dissatisfaction and prevent overeating among the general population in China.

Conclusions

In this study, we used multiple linear regression and structural equation modeling to explore the complex structural relationship between body dissatisfaction and overeating. We found that body dissatisfaction may be directly and indirectly be associated with overeating. As a mediating factor in structural equation modeling, exercise may provide strategies to reduce body dissatisfaction and prevent overeating.

Abbreviations

BMI	Body mass index
C-DEBQ	Chinese-Dutch Eating Behavior Questionnaire
PARS-3	Physical Activity Rating Scale 3
PA	Physical activity
RE	Restrained eating
BD	Body dissatisfaction
SDS	Self-Depression Scale score
EE	Emotional eating
RMSE	Root mean square error
CFI	Comparative fit index
RMSEA	Root mean square of the error of approximation

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Author contributions

Study design: Z.Y., W.Y., G.H., C.W. and M.H. Data collection: Y.W. and G.L. Data analysis: Z.Y. Manuscript writing: Z.Y. and M.H. All authors reviewed the manuscript.

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Data availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

During the investigation, investigators need to explain in detail to the research subjects that the data obtained from this investigation is only used for scientific research activities and will not disclose personal information. They should actively answer any unclear questions when students fill out the questionnaire and assist students in completing the questionnaire smoothly. This study was approved by the ethics committee of the Gannan Medical University, China, No: 2021110. This study was conducted according to the guidelines in the Declaration of Helsinki, and all study participants provided informed consent, agreeing to the required measurement and survey completion procedures. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication
No applicable.

Competing interests
The authors declare no competing interests.

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