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Unveiling the mediating role of self-esteem in the relationship between physical activity and BMI: A structural equation modeling study in adolescents

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ABSTRACT

The purpose of this study was to examine the mediating effect of self-esteem on the relationship between physical activity and Body Mass Index (BMI) in adolescents. Two hundred and sixty-nine adolescents completed the Self-Esteem Scale, the International Physical Activity Questionnaire (IPAQ), and BMI measurements. The Zhengzhou Education Authority facilitated data collection. We used Partial Least Squares (PLS) software for data analysis to evaluate the mediating effect of self-esteem. The results found that physical activity significantly improved self-esteem (β = 0.520, t = 12.881, p <.05) and negatively affected BMI (β = -0.404, t = 7.658, p <.05). The analyses of the Structural Equation Model (SEM) showed that self-esteem demonstrated a significant negative effect on BMI (β=-0.181, t=2.965, p<.05) and mediated the relationship between physical activity and BMI, accounting for 20.6% of the total effect. Thus, elevating adolescents' self-esteem may lead to a direct and indirect reduction in BMI by promoting a heightened inclination towards physical activities. This research indicates that strategies to enhance adolescent health should broaden their focus beyond merely increasing physical activity and include efforts to boost self-esteem. It provides fresh perspectives on the intricacies of adolescent physical health, emphasizing the intricate relationships among physical activity, self-esteem, and BMI.

Contribution/Originality: This study introduces a novel approach by applying Partial Least Squares Structural Equation Modeling (PLS-SEM) to explore the mediating role of self-esteem between physical activity and BMI in adolescents. It uniquely analyzes an extensive dataset from Zhengzhou's junior high schools, offering fresh insights into adolescent health promotion mechanisms.

1. INTRODUCTION

A clear trend has gradually emerged in globalization and urbanization: unhealthy diets and sedentary lifestyles are rapidly spreading worldwide. To effectively assess and monitor this phenomenon, the BMI has been widely accepted in the medical and academic communities as a critical evaluation tool [1-4]. It is noteworthy that a specific demographic whose BMI not only directly reflects their physical health status but is also closely linked to their psychological and social health, as well as the overall quality of life [5-10]. Moreover, the obesity trend continues to rise and shows no signs of reversing based on the World Health Organization's report [11]. Such a situation undoubtedly poses a significant threat to adolescents' future health and quality of life. Thus, the issue of BMI in

adolescents has undoubtedly become a significant focus in the global public health field in the 21st century (see [12, 13]).

Over the past few decades, the issue of obesity and physical activity among adolescents has become a significant public health concern [14, 15]. In China, adolescence was characterized by a lack of physical activity. Even more concerning, by 2016, the number of obese adolescents aged 5 to 19 in China had surpassed that of any other country in the world, making it the highest globally [16]. However, adolescence is a critical period of physical and mental development characterized by physiological and psychological changes. Adolesecnts' physical health, psychological well-being, and social well-being closely corelate with their BMI during this stage. Dietz [17] early on pointed out from a macro perspective that many diseases related to adult obesity often originate from obesity states during childhood and adolescence. Subsequent research has further supported this viewpoint. For instance, a 20-year longitudinal study by Kvaavik, et al. [18] highlighted the importance of BMI during adolescence as a critical predictor of the risk of overweight in adulthood. This finding has been further confirmed in studies by Wang, et al. [19] and Stovitz, et al. [20] both of which indicated that adolescents with higher BMIs face a significantly increased risk of obesity in adulthood.

1.1. Literature Review on Relation of Self-Esteem, Physical Activity, and BMI

In recent years, the escalating global concern regarding adolescent obesity has prompted numerous studies to focus on utilizing BMI as a pivotal indicator for assessing adolescents' weight status. Current research on BMI delineates several directions: 1). Establishment of BMI Standards: Given the necessity to adjust BMI standards in accordance with adolescents' growth and development, research endeavors concentrate on establishing BMI standards, delineating BMI ranges tailored to different age groups of adolescents, and defining cut-off points for overweight and obesity [21]. Health Implications of BMI: Because higher or lower BMI is linked to higher or lower health risks, some studies look into the effect of high or low BMI and how it relates to a number of diseases in teens, such as metabolic syndrome, cardiovascular disease, and diabetes [22, 23]. Socio-Cultural Factors Influencing BMI: Sociological and public health perspectives contribute to studies analyzing how familial, scholastic, and community environmental factors impact adolescents' BMI. These studies propose social policy recommendations aimed at ameliorating adolescents' BMI [24, 25]. BMI Management and Intervention Strategies: Another segment of research investigates diverse BMI management techniques, encompassing dietary regulation, physical activity promotion, and cognitive-behavioral therapy. These studies furnish concrete and practicable plans for BMI control among adolescents [26, 27]. This comprehensive spectrum of research underscores the multifaceted nature of addressing adolescent obesity and highlights the necessity for interdisciplinary approaches to tackle this pressing public health issue effectively.

Further, BMI also significantly influences adolescents' academic and psychological well-being beyond its impact on physical health. Daniels [28] highlighted academic challenges faced by adolescents with higher BMIs, while Harriger and Thompson [29] pointed out psychological and social issues such as self-esteem, depression, bullying, and social isolation. Several determinants contribute to daily physical activity and obesity at the individual level, emphasizing the importance of a holistic understanding, encompassing cultural, social, and personal dimensions [30]. In the realm of personal factors, self-esteem holds a crucial position, characterized as an individual's evaluation of positive qualities within their self-description [31, 32]. Global self-esteem includes sub-domains like social, cognitive, and self-esteem, with specific importance attached to sport competence, body attractiveness, physical strength, and physical condition [33]. Research suggests that levels of self-esteem play a crucial mediating role in anticipating subsequent behavioral responses, such as engaging in physical activity [30, 34]. Persistently tracking and regulating BMI among adolescents is crucial, given its impact on physical health, mental wellness, and social relationships.

International research has constructed a knowledge system regarding adolescent BMI from various perspectives, providing essential references for future formulation of policies on adolescent weight management. Research in China broadly categorizes the impact of physical activity on BMI among Chinese adolescents into five main types: (1) Studies directly investigating the impact of physical activity on BMI (e.g., [35-37]); (2) Studies focusing on how to increase physical activity among adolescents to reduce their BMI (e.g., [38-40]). (3) Research on external environmental factors influencing physical activity and indirectly affecting BMI, including the impact of urbanization levels or regional characteristics [41-43] and the influence of socio-economic status (e.g., [44-46]). (4) Studies on personal traits or lifestyles affecting physical activity, including gender differences (e.g., [47, 48]); sleep patterns (e.g., [49, 50]); dietary habits (e.g., [51-53]). (5) Research on achieving psychological health and reducing BMI through physical activity: These studies explore how physical activity affects the psychological health of adolescents, thereby influencing their BMI (e.g., [54, 55]).

1.2. The Interplay Between Physical Activity, Self-Esteem, and BMI

Within the realm of health research over recent decades, the intricate links among adolescent self-esteem, their engagement in physical activities, and Body Mass Index (BMI) have garnered significant attention. These elements intertwine to mirror not only the physical and psychological well-being of adolescents but also their social interactions and academic achievements, unveiling a web of complex interdependencies. Of particular importance, findings from prior studies underscore the beneficial role that engagement in physical activities plays in bolstering the self-esteem of young individuals. For instance, Dishman, et al. [56] present evidence that participation in physical activities can notably elevate the self-esteem levels among adolescents, which may, in turn, exert a favorable influence on their BMI, as suggested by Goldfield, et al. [57]. Furthermore, Basterfield, et al. [58] contribute to this discourse by demonstrating the impact sustained physical activity has on the BMI of adolescents.

However, although existing research has confirmed the direct relationship between physical activity, self-esteem, and BMI, there still needs to be a more profound understanding of how self-esteem mediates between physical activity and BMI. We hypothesize that physical activity enhances adolescents' self-esteem, contributing to healthier eating behaviors and effective weight control, ultimately impacting BMI. This understanding offers more profound insights into adolescent health behaviors and provides essential references for formulating effective health promotion strategies.

In summary, the interplay among physical activity, self-esteem, and obesity in adolescents is profoundly significant, shedding light on crucial considerations for both future research and practical applications. Amidst the escalating concerns regarding obesity rates among youths, a vast array of investigations have been undertaken by professionals in the field. Yet, the majority of these inquiries have primarily concentrated on the direct impact of physical activity on obesity, often overlooking the intricate psychological underpinnings that might play a role, particularly how self-esteem intertwines with obesity and physical activity. To bridge this research void, our study introduces innovations on several fronts: Initially, we focus our examination on children and adolescents from Mainland China to delve into BMI-related issues prevalent within this demographic. In terms of how we do things, we use a structural equation models that combines physical activity, self-esteem, and BMI into a single framework to show how these variables change overtime. Furthermore, our investigation uniquely probes the role of self-esteem as a mediating factor in the relationship between physical activity and BMI. Our objective is to uncover the extent to which self-esteem, as a psychological factor, influences the propensity for physical activity and susceptibility to obesity among adolescents. Should self-esteem serve as a mediator in this context, our findings are poised to offer innovative perspectives and avenues for subsequent intervention strategies, highlighting the promotion of self-esteem to indirectly foster a greater inclination towards physical activity and mitigate obesity risk.

Moreover, it's critical to acknowledge the diversity in existing studies, which may reflect regional, cultural, and socio-economic variances. Such differences could render the findings less universally applicable across various

adolescent populations. For example, the hypothesis by Kaminsky and Dewey [59] posits that engaging in physical activity might bolster self-esteem and consequently lead to a healthier BMI. This theory further implies that maintaining a healthy BMI could, in turn, elevate self-esteem and motivate increased physical activity. This underscores the intricate, two-way interactions among these elements.

Integrating the insights from previous studies, our research seeks to investigate the intermediary role of self-esteem in the connection between physical activity and BMI. Through examining this underlying mechanism, we aim to shed light on novel approaches for fostering adolescents' healthy development. Our goal is to elucidate the process by which physical activity may impact BMI through the enhancement of self-esteem, and to assess if such dynamics are consistent across various cultural, regional, and socio-economic contexts. This investigation promises to unveil a new understanding of the intricate interplay among physical activity, self-esteem, and BMI in young individuals, offering crucial direction for the development of holistic health promotion strategies targeting the youth.

2. METHODS

2.1. Research Design

A cross-sectional study was used with questionnaire method in this study. An online tool was utilized during the data collection. The first step involved identifying the research population and sample. With the assistance and cooperation of local educational institutions and school principals, the rigor and accuracy of the research were ensured. We established an effective communication mechanism to ensure that the sample accurately represented middle and high school students in Zhengzhou City, both in terms of breadth and depth.

2.2. Participants

The participants in this study were 269 students aged 13-18 years (M =15.55 years; SD = 1.55) who were recruited from 26 secondary schools in Zhengzhou City, Hebei Province. Each participant was asked to read and complete the consent form approved by the university's research committee. The participants consisted of 98 males (36.4%) and 171 females (63.6%), the average height of the participants was 1.66 meters (SD=0.98), the average weight was 51.77 kg (SD=9.47), and the average Body Mass Index (BMI) was 18.74 (SD=2.24). In terms of weight status, 33 participants (12.3%) were underweight, 222 (82.5%) were standard, 11 (4.1%) were overweight, and 3 (1.1%) were obese. In terms of activity level, participants averaged 478.48 minutes per week of high-intensity activity, 663.22 minutes per week of moderate-intensity activity, and 859.22 minutes per week of low-intensity activity, with a total average weekly activity duration of 20000.91 minutes. The distribution of age, gender, weight status, and activity level in this sample effectively reflects the general situation of students aged 13 to 18 in Zhengzhou City.

2.3. Research Instrument

SES (Self-Esteem Scale). This scale, developed by Rosenberg in 1965, is widely used in self-esteem research, including among adolescents and adults. The scale consists of 10 items, 5 of which are scored positively, mainly assessing an individual's "sense of self-affirmation." On the other hand, the other five items receive negative scores, which primarily gauge the individual's "sense of self-negation." Combined, these two types of items comprehensively evaluate an individual's overall perception of self-worth and self-acceptance. This scale uses a four-point scoring system, where 1 point represents strong disagreement, and 4 points represent strong agreement. A higher score from a participant indicates a higher level of self-esteem. This scale demonstrates excellent data fit in the confirmatory factor analysis, showing its solid construct validity. Synthesizing numerous studies, the Rosenberg Self-Esteem Scale consistently exhibits reliable and practical characteristics, whether applied in 53 countries, compared among different population groups, or analyzed for internal consistency among the SES items

[60-62]. Therefore, we can confirm that the SES is a self-esteem evaluation tool with superior reliability and validity.

IPAQ (International Physical Activity Questionnaire). The World Health Organisation (WHO) and researchers from multiple countries have co-developed IPAQ, a self-administered short-form questionnaire, since 1997. It demonstrates good reliability and validity after being validated over many years in numerous countries and translated into various languages for research [63, 64]. According to the IPAQ processing and analysis guidelines, physical activity levels are divided into low (3.3 METs), moderate (4 METs), and high (8 METs) standard levels. A single-factor variance analysis of these three activity levels shows significant results, with Eta Square values of .557, .347, and .547, respectively, demonstrating high correlation and high credibility. In scoring, this study refers to the IPAQ data processing and analysis guide by Fan, et al. [65]. Each level of activity's metabolic equivalent (MET) is multiplied by its duration (minutes per day) and frequency (days per week), yielding the weekly metabolic equivalent. The higher the metabolic equivalent, the greater the physical activity [65].

BMI (Body Mass Index). In this study, body mass index (BMI) was based on measurements of individual height and weight [66]. The validity and accuracy of BMI in different contexts support incorporating age and sex into the BMI assessment framework, which is particularly important in assessing obesity in children and adolescents [67, 68]. Self-reported and measured BMI classified adolescents into four groups: underweight, average weight, overweight, and obese [68]. This classification uses the formula BMI=weight (kg)/height (meters)^2 and incorporates critical variables such as age and gender into our assessment framework to gain insights into obesity patterns among adolescents.

2.4. Statistical Analysis

To ensure the accuracy of the analysis, this study employed various statistical techniques for data processing and analysis. We performed descriptive statistical analysis using the SPSS 23.0 software to assess and organize the study participants' demographic information, physical activity levels, and BMI values. Additionally, the PLS method was used to establish and test the SEM to validate the proposed hypotheses. In evaluating the structural equation model, following the recommendations of Anderson and Gerbing [69] the process was divided into three steps:

(1) Evaluation of the measurement model to confirm the research framework and assess its reliability and validity.
(2) Evaluation of the structural model, conducting collinearity diagnostics, predicting, and explaining path effects, and testing the model's fit and the causal relationships between paths.
(3) Verification of the mediation hypotheses to examine the proposed intermediary relationships in this study.

2.5. Study Limitations

This study undoubtedly has potential limitations that should be considered when interpreting the results:

(1) Sample Representativeness: While the study sample mainly consists of adolescents from Zhengzhou City, Henan Province, this regional specificity might limit the generalizability of the findings to other populations. Cultural, socio-economic, and educational differences across regions can significantly influence behaviors and perceptions related to physical activity, BMI, and self-esteem. Future research could benefit from a more diverse sample that includes various geographical areas to enhance the external validity of the findings.
(2) Self-reporting Bias: Depending on participants' self-reported information introduces the potential for bias in reporting. Individuals may either exaggerate or downplay their levels of physical activity and self-esteem, influenced by the desire to appear socially acceptable or due to inaccuracies in memory. We recommend integrating objective assessments to enhance the reliability of future research. For instance, employing devices

like accelerometers could accurately measure physical activity levels, and adopting standardized, clinically endorsed scales for self-esteem evaluation could provide a robust method to verify self-reported data.

(3) Structural Equation Modelling (SEM) Limitations: The effectiveness of SEM is contingent on the accuracy of model setup and theoretical assumptions. Biases in these areas could skew results, leading to incorrect interpretations. It is crucial for future studies to critically assess the model's assumptions and consider alternative models to ensure robust results.

(4) Cross-sectional Design: As a cross-sectional study, it cannot establish causality between variables. Longitudinal designs in future research could help determine the directionality and causality of the relationships among physical activity, self-esteem, and BMI.

(5) Measurement Tool Limitations: While the study used widely accepted tools like the Rosenberg Self-Esteem Scale and IPAQ, these tools might only comprehensively capture some relevant psychological or behavioral variables. Cultural and linguistic differences can also influence their reliability and validity. Subsequent research should explore additional or alternative measurement tools and validate them in different cultural settings.

(6) Emphasizing Research Value: Despite these limitations, the study provides valuable insights into the interplay between physical activity, self-esteem, and BMI among adolescents. These findings lay a foundation for future research, suggesting the need for a multi-faceted approach to studying adolescent health.

By acknowledging and addressing these limitations, future research can build on the current study's findings to deepen the understanding of adolescent health behaviors and develop more effective intervention strategies.

3. RESULTS AND DISCUSSION

Partial Least Squares Structural Equation Modeling (PLS-SEM) is a way to do statistical analysis that works well with small samples, data that isn't normally distributed, and models that have more than one indicator or path. It can handle various independent and dependent variables, solve multicollinearity problems, and efficiently handle outliers and missing data. Moreover, PLS-SEM has powerful predictive abilities and can take reflective, formative, and single-direction structures without considering identification or positivity issues. These characteristics make PLS-SEM a vital tool widely used in various research contexts Hair, et al. [70].

Hair, et al. [71] pointed out that PLS-SEM is a better choice when the relationships between variables in structural models or conceptual measurements need to be more precise and the research is more exploratory than confirmatory. We chose to use PLS-SEM for analysis because it fits the needs and limitations of this study. We divided the analysis into three stages: assessing the measurement model, assessing the structural model, and scrutinizing the mediation.

3.1. Evaluation of the Measurement Model

Research framework model. First, we need to establish a research framework. As shown in Figure 1 this study includes three primary constructs: self-esteem, physical activity, and BMI values, all of which are first-order constructs. On this path, self-esteem affects both physical activity and BMI values. At the same time, physical activity not only influences BMI values but also primarily plays a mediating role between self-esteem and BMI values.

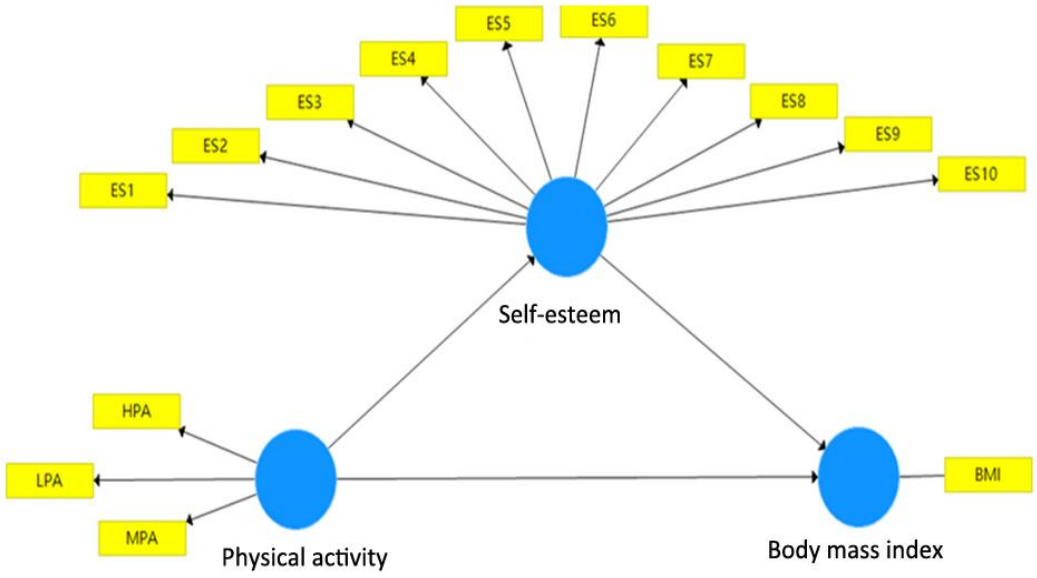

Figure 1. Research framework model.

Indicator reliability. To assess the reliability of each observable variable's indicators, we checked the standardized factor loadings of each item (as shown in Figure 2). The factor loadings for self-esteem ranged from 0.505 (t=4.960) to 0.670 (t=8.195), while those for physical activity ranged from 0.571 (t=8.533) to 0.749 (t=18.573). Thus, the factor loadings for both constructs were more significant than 0.5 and ranged between 0.505 and 0.749, all with substantial results. This indicates that each item has good indicator reliability [72]. However, as BMI is a single-variable indicator, evaluating its indicator reliability or factor loadings is unnecessary.

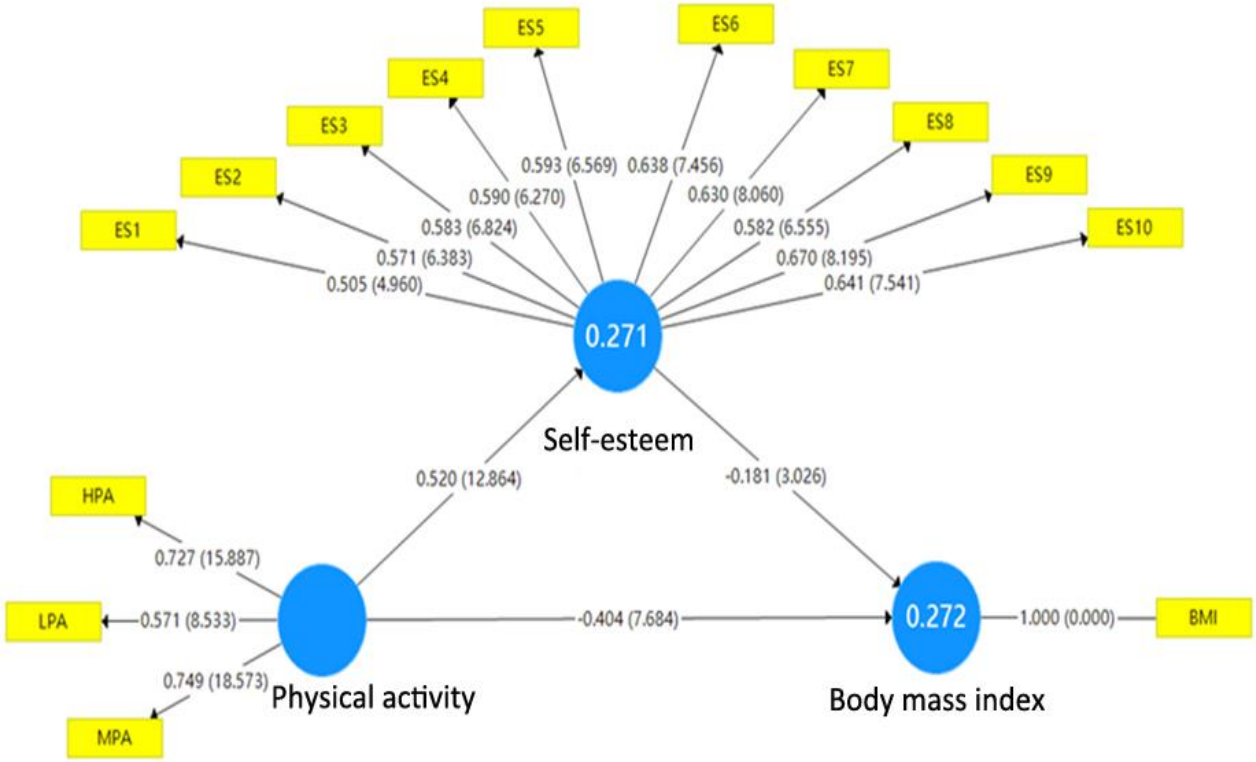

Figure 2. Standardized factor loadings and t-values.

Internal consistency. For each construct's internal consistency evaluation, Cronbach's alpha and Composite Reliability (CR) metrics were computed, as shown in Table 1. The Cronbach's alpha value for the self-esteem construct was determined to be 0.803, with a CR value of 0.850, exceeding the threshold of 0.7, which signifies robust internal consistency for self-esteem [73-75]. Since BMI and physical activity are measured by single indicators, assessing their internal consistency is not required.

Convergent validity. Evaluation of convergent validity for each construct involved computing the Average Variance Extracted (AVE), detailed in Table 1. The AVE result for the self-esteem construct was 0.502, translating to a 50.2% variance explanation, surpassing the 50% benchmark and indicating strong convergent validity for self-esteem [76, 77]. For single variables such as BMI and Physical Activity, the AVE was calculated to be 1, signifying a complete variance explanation and thus confirming their impeccable convergent validity.

Table 1. Construct reliability and validity test.

Constructs	Cronbach's alpha	CR	AVE
Self-esteem	0.803	0.85	0.502
Physical activity	1	1	1
BMI	1	1	1

Discriminant validity. This study evaluated the first-order constructs of self-esteem, physical activity, and BMI for discriminant validity (see Table 2).

The analysis revealed that the square roots of the AVE for BMI and physical activity were 1.000, and for self-esteem, it was 0.709. Specifically, the correlation coefficients of BMI with self-esteem and physical activity were -0.391 and -0.505, respectively, lower than their respective square roots of AVE. Similarly, the correlation coefficient of self-esteem with physical activity was 0.521, also lower than their square roots of AVE. So, the square roots of the AVE of each construct were more important than their links to other constructs, which means they meet the Fornell-Larcker criterion for discriminant validity [76].

These data demonstrate that the discriminant validity of the constructs BMI, self-esteem, and physical activity has been confirmed, with each construct having a higher correlation with itself than with other constructs, thereby ensuring the uniqueness of each construct and the validity of the research.

Table 2. Discriminant validity test.

Constructs	Body mass index	Physical activity	Self-esteem
Body mass index	1.000		
Physical activity	-0.505	1.000	
Self-esteem	-0.391	0.521	0.709

3.2. Evaluation of the Structural Model

At this point in the PLS-SEM structural model evaluation process, we will do what many other researchers have suggested and look at the path coefficients and their significance, as well as the model's ability to predict, explain, and fit.

Indicator Collinearity Diagnosis. Table 3 presents the Variance Inflation Factor (VIF) values for each indicator in the model. The analysis reveals that the VIF for Self-Esteem, Physical Activity, and Body Mass Index are all less than 5, indicating that the issue of collinearity in the model is not severe [70]. Therefore, potential collinearity problems are not likely to have a detrimental impact on the path model in the future.

Table 3. Indicator collinearity test (VIF).

Self-esteem		Physical activity	
Indicator	**VIF**	**Indicator**	**VIF**
ES1	2.209	Physical activity	1
ES2	2.637	**Body mass index**	
ES3	2.236	**Indicator**	**VIF**
ES4	2.573	Body mass index	1
ES5	2.028		
ES6	2.507		
ES7	2.499		
ES8	2.31		
ES9	3.327		
ES10	3.568		

Path Relationship Test. The test results shown in Table 4 indicate that the impact of Physical Activity on Self-Esteem ($t=12.881>1.96$, $p<.05$) and on Body Mass Index ($t=7.658>1.96$, $p<.05$) are both significant. Furthermore, the effect of self-esteem on Body Mass Index ($t=2.965>1.96$, $p<.05$) is also significant. According to this study's results, physical activity significantly influences both self-esteem and Body Mass Index. At the same time, self-esteem also significantly affects Body Mass Index. This implies that self-esteem may mediate in the process of physical activity influencing Body Mass Index, but this requires further confirmation through a mediation effect test. These findings help to deepen our understanding of the impact of self-esteem on Body Mass Index and its mechanisms and provide crucial theoretical guidance for the practical management of Body Mass Index.

Model Prediction and Explanation Power Evaluation. Table 4 provides insights into physical activity, self-esteem, and Body Mass Index dynamics. Highlighting the effect of physical activity on self-esteem, the analysis reveals a moderate predictive strength ($R^2=0.271$, indicating a moderate effect size, which situates between 0.25 and 0.50) as identified by Hair Jr, et al. [78]. This suggests that fluctuations in physical activity account for 27.1% of the variations in self-esteem, playing a significant role in its predictive capacity. Nonetheless, it is crucial to acknowledge that other variables influence the remaining 72.9% of self-esteem variance. Despite the evident correlation between physical activity and self-esteem, the relatively small effect size ($f^2=0.163$), being below the threshold of 0.35, points to a minimal influence, emphasizing the need to consider a broader spectrum of factors for accurately explaining changes in Self-Esteem [79].

Next, look at the influence of Physical Activity and Self-Esteem on Body Mass Index. The predictive power data shows that Physical Activity and Self-Esteem can moderately predict the changes in Body Mass Index ($0.25 \leqq R^2=0.272 \leqq 0.50$) [78]. This means that changes in Physical Activity and Self-Esteem can explain 27.2% of the variation in Body Mass Index, demonstrating the influence of these two factors on Body Mass Index. However, regarding explanatory power, the influence of Physical Activity ($f^2=0.371$) exceeds 0.35, indicating a strong explanatory power on Body Mass Index [79] suggesting Physical Activity plays a significant role in the changes in Body Mass Index. On the other hand, the explanatory power of Self-Esteem on Body Mass Index ($f^2=0.186$) is less than 0.35, indicating its influence is relatively weak [79] meaning the impact of changes in Self-Esteem on Body Mass Index is relatively tiny.

In summary, these findings reveal the subtle relationships between Physical Activity, Self-Esteem, and Body Mass Index, providing valuable insights into how these variables influence each other. This is significant for further exploring and optimizing weight management strategies in practice.

Model Fit Test. The analysis results (see Table 4) indicate that this model has a high fit ($Gof=0.449>0.36$), representing a high degree of match between the theoretical model and the sample data [79].

In summary of the results above, this study has delved into the impact of Physical Activity on Body Mass Index through the structural model. Regarding the assessment of the measurement model, all indicators' reliability and validity reached an acceptable level, and the collinearity issue of the model is mild. Regarding the structural model

assessment, the results show that Physical Activity significantly negatively impacts Body Mass Index. Self-Esteem might mediate, but further mediation effect tests need to be conducted. Regarding the model fit, the results show that this model has a high fit, meaning there is a high degree of match between the theoretical model and the sample data.

Table 4. Path model evaluation test.

Relationship	Path coefficient	t	R^2	f^2	Gof
Physical activity --> Self-esteem	0.520*	12.881	0.271	0.163	0.449
Physical activity -->Body mass index	-0.404*	7.658	0.272	0.371	
Self-esteem--> Body mass index	-0.181*	2.965		0.133	

Note: * p<0.05.

3.3. Evaluation of Mediation Hypotheses

This research aims to explore the mediating influence of Self-Esteem on the link between Physical Activity and Body Mass Index. The analysis, as delineated in Table 5, indicates that Self-Esteem significantly mediates this relationship (t=4.895>1.96, p<.05), thus affirming the proposed hypothesis. These findings underscore Self-Esteem's pivotal mediating role in connecting Physical Activity with Body Mass Index.

Further analysis from the perspective of Variance Accounted For (VAF) shows that the mediating effect of Self-Esteem (20% <VAF =20.6% <80%) can be considered a partial mediation. This means that part of the impact of Physical Activity on Body Mass Index is realized through Self-Esteem. This provides a new perspective on how Physical Activity may affect Body Mass Index through Self-Esteem.

In addition, considering the total effect of Physical Activity on Body Mass Index, the overall impact is -0.509. This full effect consists of the direct effect of Physical Activity on Body Mass Index of -0.404 and the indirect impact through Self-Esteem of -0.105. These results show that Self-Esteem partially mediates the effects of Physical Activity on Body Mass Index, providing new insights into how Physical Activity affects Body Mass Index.

In conclusion, the impact of Physical Activity on the Body Mass Index of adolescents is not only direct but also includes indirect effects through Self-Esteem. This result has valuable theoretical and practical implications for understanding how Physical Activity affects Body Mass Index through Self-Esteem and understanding the interactions between these variables, helping to enhance understanding and practice of Body Mass Index management strategies for adolescents at a deeper level.

Table 5. Mediation effect test.

Independent variable	Mediator variable	Dependent variable	Direct effects	Indirect effects	Total effects	VAF
Physical activity	Self-esteem	Body mass index	-0.404* (7.658)	-0.105* (4.895)	-0.509* (11.875)	20.6%

Note: * p<.05. The number in the parenthesis represents the t-value.

3.4. Discussion

3.4.1. Discussion on the Verification of the Self-Esteem mediation Hypothesis

This study confirms that Self-Esteem partially mediates between Physical Activity and Body Mass Index (BMI), providing a new perspective on how Physical Activity influences BMI through Self-Esteem. Our results show that Physical Activity can not only directly affect BMI but can also indirectly affects BMI by improving Self-Esteem.

This finding emphasizes the importance of mental health in maintaining a lower BMI and encouraging Physical Activity. Many studies have found that high self-esteem can effectively encourage Physical Activity and maintain a healthy weight [80-82]. In addition, Self-Esteem also affects individual dietary choices and behavior, affecting BMI [83, 84]. Therefore, improving adolescents' self-esteem might be an effective strategy. It can directly

improve their BMI and indirectly improve their BMI by increasing their willingness to participate in Physical Activity [85].

From existing research, we have recognized that Physical Activity positively impacts mental health, including improving Self-Esteem [81, 86]. Further, someone with high Self-Esteem tends to make healthier lifestyle choices, which usually leads to a lower BMI [87]. In other words, when individuals have a higher recognition and sense of value for themselves, they are more likely to choose a healthy diet, an active lifestyle, and maintain regular Physical Activity, all critical factors affecting BMI.

Insights from our investigation reveal the significant intermediary role of Self-Esteem within the interplay of Physical Activity and Body Mass Index (BMI). Such findings spotlight psychological well-being's essential role in achieving a desirable BMI and motivating participation in exercise routines. Research across various studies highlights how a robust sense of self-esteem contributes to adopting a lifestyle encompassing consistent engagement in physical activities and attaining a healthy weight [80, 81, 88]. Additionally, insights from specific research suggest that an individual's sense of Self-Esteem could markedly influence their food choices and habits, thus directly impacting their BMI [83, 84]. Therefore, interventions aimed at elevating the Self-Esteem of adolescents could serve as an effective tactic not only for directly enhancing their BMI but also for fostering a more active involvement in Physical Activity, potentially leading to a beneficial indirect effect on their BMI [85]. This research paves the way for novel approaches and insights into devising strategies to improve adolescents' physical health.

However, we must also acknowledge that numerous factors may influence this mediation relationship. For example, gender, age, and socioeconomic status may affect the relationship between Physical Activity, Self-Esteem, and BMI. Existing research shows that Physical Activity, Self-Esteem, and BMI during adolescence may be affected by gender [89, 90]. Age may affect adolescents' physical self-concept, affecting their Self-Esteem and BMI [91]. In addition, socioeconomic status may also affect adolescents' dietary habits, Physical Activity, and Self-Esteem, which in turn affect their BMI [92, 93]. Therefore, we must consider these possible influencing factors and moderating variables in future research to provide a more comprehensive and in-depth understanding.

Collectively, the results from our study broaden the comprehension of how Physical Activity, Self-Esteem, and Body Mass Index (BMI) interact while also opening avenues for forthcoming scholarly inquiries. More specifically, the insights garnered suggest a tangible approach: fostering self-esteem in adolescents could serve as a critical mechanism to improve their BMI and boost their inclination towards engaging in Physical Activity. Looking ahead, there is an opportunity for future studies to investigate additional variables that may act as mediators and to evaluate diverse approaches to enhance the Self-Esteem of young individuals to decipher strategies for effective BMI improvement more deeply.

3.4.2. Discussion of Research Limitations

This study confirms that self-esteem partially mediates the relationship between physical activity and Body Mass Index (BMI), providing a new perspective on how physical activity influences BMI through self-esteem. Our results show that physical activity directly affects BMI and indirectly influences BMI by improving self-esteem.

This discovery underscores the pivotal role of mental well-being in sustaining a healthier Body Mass Index (BMI) and fostering engagement in physical exercise. A wealth of research indicates that elevated self-esteem can boost engagement in exercise and help achieve and retain a healthy physique [94, 95]. Moreover, self-esteem influences dietary habits and behaviors, impacting BMI [83, 84]. Enhancing adolescents' self-esteem could be an impactful approach, potentially benefiting their BMI and amplifying their motivation for participating in physical activity [85].

Current studies have established a link between physical exercise and enhanced mental well-being, notably boosting self-esteem [81, 86]. Moreover, individuals possessing robust self-esteem often opt for healthier living

habits, which generally contribute to a healthier Body Mass Index (BMI) [96]. Put differently, when people hold themselves in higher esteem and appreciate their worth, they are inclined towards selecting nutritious foods, embracing an energetic lifestyle, and committing to consistent physical activities, all essential elements influencing BMI.

This research indicates that gender, age, and socioeconomic status may affect the relationship between physical activity, self-esteem, and BMI. For example, gender may influence adolescents' participation in physical activity and levels of self-esteem [89, 90]. Age may affect adolescents' physical self-concept, thus impacting their self-esteem and BMI [91]. Additionally, socioeconomic status might influence adolescents' dietary habits, physical activity, and self-esteem, which affects their BMI [92, 93]. Therefore, these potential influencing factors and moderating variables must be considered in future research to provide a more comprehensive and in-depth understanding.

In summary, the insights gained from our study shed light on the dynamic interplay among physical activity, self-esteem, and Body Mass Index (BMI), paving the way for further investigations. Notably, the data imply that bolstering adolescents' self-esteem could be a pivotal approach to positively influencing their BMI and enhancing their propensity for participating in physical activities. Future inquiries could delve into additional mediating factors and evaluate varied approaches aimed at elevating the self-esteem of young individuals, thereby offering a more holistic perspective on effective BMI improvement strategies.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

This research aimed to explore the interrelationships and mutual interactions between physical activity, self-esteem, and BMI. The outcomes of the study reveal that physical activity influences BMI in a dual manner: directly, and indirectly by enhancing self-esteem, which in turn affects BMI. Such a discovery carries significant implications for both theoretical frameworks and practical applications.

Theoretically, the research corroborates the vital roles of physical activity and self-esteem in influencing physical health, particularly regarding changes in BMI. It affirms the inverse relationship between physical activity and BMI and unveils the mediating function of self-esteem within this dynamic. In essence, physical activity's impact on BMI extends beyond a direct influence; it also indirectly contributes to BMI reduction by boosting self-esteem levels. This insight offers a novel lens through which to view and deepen our comprehension of the complex ties binding physical activity, self-esteem, and BMI.

On a practical level, the research results carry essential insights. Firstly, physical activity can effectively reduce BMI, emphasizing the importance of increasing physical activity. Furthermore, enhancing self-esteem is also worth considering, as it can indirectly lower BMI by influencing physical activity. This reminds us of improving self-esteem when formulating health promotion strategies.

4.2. Limitations

We should acknowledge several limitations in this study. First, this study did not directly explore the influence of factors such as gender, age, and socioeconomic status on the relationship between physical activity, self-esteem, and BMI. These variables may affect the relationship between these three elements, which is a significant limitation of this study. Future research needs to explore the impact of these factors further. Second, although this study provides new perspectives, there are still limitations. For instance, this research's cross-sectional study design fails to establish a cause-and-effect relationship. Additionally, the data in this study relies on self-reporting, which may result in reporting bias. Future research should consider these issues and further explore the relationship between physical activity, self-esteem, and BMI. The third limitation is that self-esteem was the only potential mediator examined in this study; however, other mediators, such as social support, body image, motivation, and body satisfaction, also need to be identified and tested. The fourth limitation is that the generalizability of the results was

constrained due to the small sample size and the limited age range and gender of all secondary school students in China. To establish the applicability of our findings to students of both sexes, various races, and different age groups, we warrant future research with larger samples.

4.3. Recommendations

Based on the above conclusions, we make the following recommendations for future research and practical work:

Firstly, future research can take factors such as gender, age, and socioeconomic status into account. This can deepen our understanding of the relationship between physical activity, self-esteem, and BMI. Secondly, for practical applications, we suggest emphasizing the importance of physical activity and self-esteem. Physical activity can directly lower BMI, while self-esteem can indirectly lower BMI through increased physical activity. Therefore, we should promote strategies to increase physical activity and self-esteem.

Moreover, our recommendations should consider individual characteristics such as gender, age, and socioeconomic status. Various groups may require distinct strategies. For adolescents, school activities can enhance their physical activity and self-esteem. For groups with low socioeconomic status, we may need to provide more support, such as by providing appropriate sports facilities and resources, and increasing education about the importance of self-esteem.

Finally, future research can further explore the relationship between physical activity, self-esteem, and BMI, especially other potential mediating and moderating variables. This will help us to more comprehensively understand the relationship between these variables and develop more effective intervention strategies.

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