Preventive Medicine Reports 41 (2024) 102718

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Mediating role of body mass index on the relationship between physical activity and physical fitness among junior high school students in Shanghai

Dan Bai [a,*], Asha Hasnimy Mohd Hashim [a], Yanna Li [b]

[a] Faculty of Social Science and Humanities, Universiti Teknologi Malaysia, Johor Bahru, Johor, Malaysia
[b] Songyi Middle School, Baoshan, Shanghai, China

ARTICLE INFO

Keywords:
Physical activity
Body mass index
Physical fitness
Junior high school students

ABSTRACT

Objectives: This study explored the relationship between physical activity (PA), body mass index (BMI), and physical fitness among junior high school students in Shanghai. **Methods:** A nationwide offline survey was conducted in Shanghai between August and December 2023, using a purposive sampling design. A total of 403 questionnaires were administered to 10 ninth-grade classes in 10 schools in Shanghai and 372 responses were included in the final analysis. Smart-PLS 4.0, structural equation modeling techniques were employed to analyze the collected data. **Results:** Light physical activity (LPA) had no influence on BMI, 800/1000 m (800/1000 M), sitting forward bend (FB), standing long jump (SLJ), 50 m (50 M), or vital capacity (VC). The results of part hypothesis supported the hypothetical model and explained that BMI had a negatively influence on 50 M, 800/1000 M and SLJ, BMI had a positively influence on VC. Moderate physical activity (MPA) had a negatively influence on BMI, but vigorous physical activity (VPA) had a positively influence on BMI, they both had influence on 50 M and FB, but had no influence on 800/1000 M, SLJ, and VC. **Conclusions:** BMI, MPA and VPA were found as pivotal factors influencing physical fitness, MPA and VPA were found to have divergent effects on BMI. This study highlighted the multifaceted nature of the relationship between PA, BMI, and physical fitness in junior high school students in Shanghai.

1. Introduction

Children and adolescents form an essential foundation of national prosperity and social progress. Children and adolescents focus on their physical fitness. Recently, the results of the National Student Physical Fitness Survey have shown that the decline in students' physical fitness has slowed down (Results of the 2014 National Student Physical Health Survey, 2015). However, the situation is still not optimistic; the rates of myopia, overweight, and obesity continue to decrease, while the rates of myopia, overweight, and obesity continue to increase (Cai et al., 2017). Physical fitness of Chinese school-aged children, including junior high school students in Shanghai, is a topic of interest. In 2016, about 3 in 10 Chinese children achieved an "excellent" or "good" fitness standard, while approximately 8 % did not meet the Chinese National Student Physical Fitness Standard (CNSPFS). Boys were more likely to not pass the fitness standards compared to girls, and children living in urban areas were also more likely to not meet minimum fitness performance levels. The Chinese Ministry of Education has emphasized the importance of physical health and fitness in schools, requiring at least two hours of exercise daily for students, with specific guidelines for different grade levels. This initiative aims to incorporate health and physical fitness into school curricula and standardized exams, highlighting the significance of PA for academic engagement and overall well-being among students (Wang et al., 2016; Wang et al., 2023; Zhu et al., 2017).

Some studies have found that the physical fitness of children and adolescents is related to the amount of PA. Most of the Kunshan people participate in PA one time or more than one time per week. They perform 30–60 min of MPA to improve physical fitness, recreation, and disease prevention (Saqib et al., 2020). The majority of the participants (32.0 %) said that the national fitness plan helps promote sports environment and health. About 28.0 % reported that the National Fitness Plan (NFP) helps promote cycling and walk environments for physical activity and health promotion and preventing non-communicable diseases (NCDs) (Menhas et al., 2021). The direct cause of the decline in physical fitness in children and adolescents is insufficient PA (Li et al., 2011). For children and adolescents in a critical period of growth and development, participating in a sufficient amount of PA daily is a fundamental guarantee for promoting their physical and mental health

* Corresponding author.
E-mail address: dan20@graduate.utm.my (D. Bai).

https://doi.org/10.1016/j.pmedr.2024.102718
Received 11 February 2024; Received in revised form 5 April 2024; Accepted 6 April 2024
Available online 8 April 2024

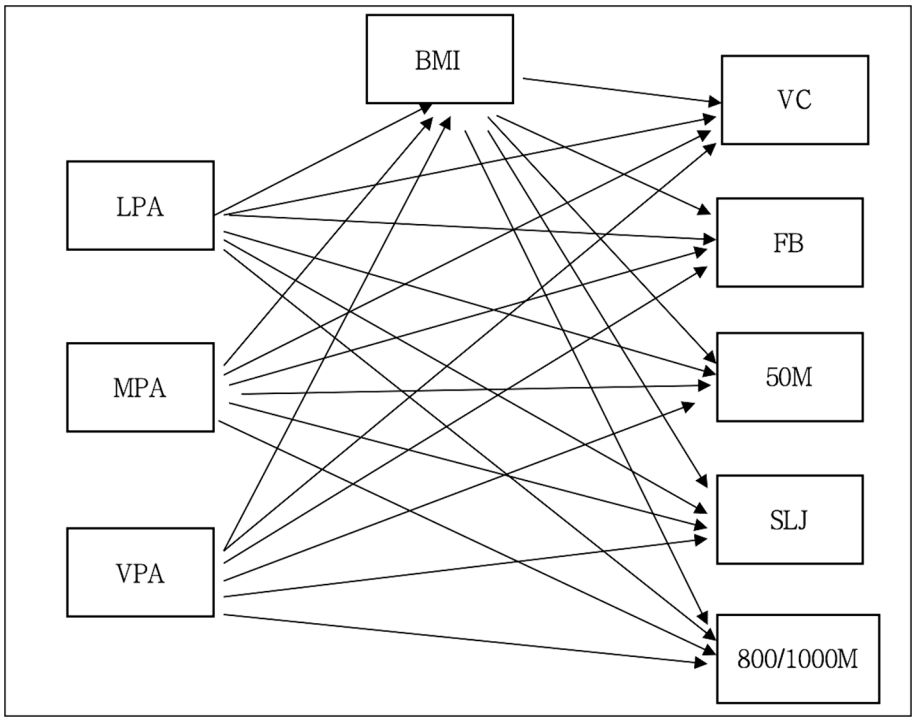

Fig. 1. Proposed hypothetical model of physical activity, body mass index, and physical fitness among Shanghai junior high school students in 2023.

development. This is extremely important for development and health in adulthood. Numerous domestic and foreign studies have found the current problem of insufficient PA among children and adolescents worldwide (Zhang et al., 2016). Most children and adolescents worldwide cannot achieve at least one hour of moderate-to-high-intensity daily exercise as recommended by the World Health Organization (WHO).

PA also plays an important role in improving the obesity problem among junior high school students. Studies by Cai et al. suggest that long-term MVPA accumulation is strongly correlated with BMI decline (Jiang et al., 2020). They used Polar Team OH1 and Actigraph wGT3X-BT equipment to explore the impact of different exercise densities on exercise energy consumption and physical fitness of 10–11-year-old students. The results showed that exercise density is the main factor affecting energy consumption and physical fitness. Jiang et al.(2020) found that MVPA in boys positively correlated with BMI. They were surveying first- and second-grade students. The variability in MVPA duration and frequency during school days and weekends is related to physical health. It was concluded that junior high school students were more active on school days than on weekends, but the MVPA activity period on school days was relatively single. MVPA complexity is a comprehensive indicator that may be closely related to junior high school students' BMI.

2. Literature review

2.1. Physical activity and physical exercise

Exercise is defined as a subset of PA that is planned, structured, and repetitive and has a final or an intermediate objective of the improvement or maintenance of one or more components of physical fitness (Siscovick et al., 1985), whereas a concept analysis indicated that the definition of PA is "any bodily movement produced by skeletal muscles that result in energy expenditure." The positive effects of PA can be achieved in different ways and do not necessarily include exercise (Dasso, 2019; Siscovick et al., 1985; Södergren et al., 2008).

2.2. BMI

BMI is used to assess body weight in relation to their height. It is commonly used as a screening tool to indicate whether a person is underweight, overweight, or within the healthy weight range. BMI was calculated by dividing a person's weight in kilograms by the square of their height in meters (kg/m^2).

2.3. Physical fitness

This study is mainly based on the "National Student Physical Fitness Standards (Revised in 2014)" promulgated by our country, which divides the physical fitness level into three parts: body shape, physical function, and physical fitness, and comprehensively evaluates it based on the "Physical Fitness Standards" Physical fitness level of middle school students. In junior high schools in Shanghai, physical fitness test items included BMI, 800/1000 M, FB, SLJ, 50 M, and VC.

3. Theoretical background

3.1. ET

Bronfenbrenner's ecological systems theory (ET) is a widely accepted explanation of how various environmental systems influence human development. This theory emphasizes the interconnectedness between different environmental factors and their impact on an individual's development. It comprises five environmental systems: microsystems, mesosystems, exosystems, macrosystems, and chronosystems. These systems range from an individual's immediate surroundings to broader cultural influences and historical events. This theory has been influential in fields such as psychology, education, and human development and has been used to understand the complex systems that influence human development (Navarro & Tudge, 2023; Staunton & Naidu, 2023).

In this study, ET considers the influence of multiple levels of the environment on an individual's behavior. It can be applied to examine how factors at the individual level (e.g., BMI and PA) interact with the microsystem (family and peers) and macrosystem (cultural and societal

norms) to influence physical fitness. Fig. 1 illustrates the conceptual framework of the study. This framework indicated the mediating effect of BMI on the relationship between different intensities of PA and physical fitness in Shanghai junior high school students through social cognitive theory (SCT) and ecology theory (ET).

4. Study hypotheses

4.1. Relationship between PA and BMI

Regular PA can help adolescents improve their physical fitness and control their weight, which can affect their BMI. The WHO recommends that children and adolescents aged 6–17 years perform 60 min or more of PA daily to improve their cardiorespiratory fitness, build strong bones and muscles, and control weight (Physical Activity Facts, 2022). Studies have also shown that physical inactivity, sedentary behavior, and low cardiorespiratory fitness are substantial risk factors for the development of chronic diseases and obesity in adolescents (van Sluijs et al., 2021). Many physically active children and adolescents have lower body fat levels than those who are less active (Hills et al., 2011; Wyszyńska et al., 2020). Therefore, promoting regular PA among adolescents is crucial to improving physical fitness and reducing the risk of obesity. Therefore, this study proposes the following hypothesis:

H1: LPA will negatively influence the BMI of junior high school students in Shanghai.

H2: MPA will negatively influence the BMI of junior high school students in Shanghai.

H3: VPA will negatively influence the BMI of junior high school students in Shanghai.

4.2. Relationship between BMI and physical fitness

Many studies on the impact of BMI on adolescent health are reviewed below from both physical and mental perspectives. From the perspective of physical health, scholars such as Yang Mengli analyzed the physical fitness data of students in Henan Province in 2014. They explored the relationship between BMI and the Physical Fitness Index of students aged 7–18. They concluded that the BMI and physical fitness ranking was as follows: normal BMI group > low and very low BMI group > high and very high BMI groups. BMI and physical fitness were also non-linear, showing a parabolic trend with age(Yang et al., 2018). Zhao Bangwei (2022) analyzed the relationship between body fat percentage, body fat index, fat-free BMI, and physical fitness. Taking 4069 children and adolescents aged 6–20 years old in Beijing as participants, a measurement difference analysis was conducted between BMI and physical test scores for body composition. It was found that BMI has a specific predictive effect on the physical fitness of adolescents, especially among boys (Zhao et al., 2022). Therefore, this study proposes the following hypothesis:

H4: BMI will negatively influence 50 M among junior high school students in Shanghai.

H5: BMI will negatively influence 800/1000 M among junior high school students in Shanghai.

H6: BMI will negatively influence FB among junior high school students in Shanghai.

H7: BMI will negatively influence SLJ among junior high school students in Shanghai.

H8: BMI will positively influence VC among junior high school students in Shanghai.

4.3. Relationship between PA and physical fitness

Regular PA has a significant effect on adolescent physical fitness. The WHO recommends that children accumulate an average of 60 min of PA daily, including aerobic, muscle strengthening, and bone strengthening exercises (Carriedo et al., 2022). Studies have observed relationships between PA and health in adolescents, with physical inactivity, sedentary behavior, and low cardiorespiratory fitness as strong risk factors for developing chronic diseases (Kumar et al., 2015). Additionally, adolescent physical inactivity likely contributes to critical global health problems, including cardiometabolic and mental health disorders (van Sluijs et al., 2021). Therefore, promoting regular PA among adolescents is crucial to improving their physical fitness and overall health. Therefore, this study proposes the following hypothesis:

H9a: LPA will positively influence 50 M among junior high school students in Shanghai.

H9b: LPA will positively influence 800/1000 M among junior high school students in Shanghai.

H9c: LPA will positively influence FB among junior high school students in Shanghai.

H9d: LPA will positively influence SLJ among junior high school students in Shanghai.

H9e: LPA will positively influence VC among junior high school students in Shanghai.

H10a: MPA will positively influence 50M among junior high school students in Shanghai.

H10b: MPA will positively influence 800/1000M among junior high school students in Shanghai.

H10c: MPA will positively influence FB among junior high school students in Shanghai.

H10d: MPA will positively influence SLJ among junior high school students in Shanghai.

H10e: MPA will positively influence VC among junior high school students in Shanghai.

H11a: VPA will positively influence 50M among junior high school students in Shanghai.

H11b: VPA will positively influence 800/1000M among junior high school students in Shanghai.

H11c: VPA will positively influence FB among junior high school students in Shanghai.

H12d: VPA will positively influence SLJ among junior high school students in Shanghai.

H13e: VPA will positively influence VC among junior high school students in Shanghai.

5. Method

5.1. Participants

This study was restricted to 9th grade students in Shanghai during the first semester of 2023–2024 and met the data curator's guidelines for protection of human subjects concerning safety and privacy. Participants were selected using a purposive sampling design. This study selected five junior high schools in urban and suburban districts of Shanghai. These are Jingan, Changning, Yangpu, Hongkou, and Xuhui in the urban district and Minghang, Songjiang, Jiading, Qingpu, and Jinshan in the suburban district. This research selected one school and one junior high school in each district. One 9th grade class was chosen to test the projects on physical fitness. All students in the class completed the questionnaires about PA to avoid confusing the concepts of PA and physical education class exercises.

5.2. Data quality control

The staff responsible for conducting tests in the experiment were divided into two categories: one was the physical tester who was responsible for conducting physical fitness tests, and the other was the questionnaire surveyor who was responsible for conducting questionnaire surveys. There was a total of 1 team leader, 3 physical testers and 1 questionnaire surveyor. Physical fitness testers needed to be trained before the test, and they must operate the physical fitness testing equipment and record and convert scores in strict accordance with the

Table 1
Demographic characteristics of the respondents of physical activity, body mass index, and physical fitness among Shanghai junior high school students in 2023.

Demographic	Category	Frequency	Percentage (%)
Gender	Male	198	53.2
	Female	174	46.8
Age	14	166	44.6
	15	188	50.5
	16	30	4.8

"National Student Physical and Health Standards (Revised in 2014)". The first fitness tests and questionnaire surveys began on 13, August 2023, ended on 5, December 2023. A total of 403 questionnaires were received, and 372 responses were included in the final analysis.

6. Measures

6.1. PA

Participants' PA was assessed by frequency in a typical week (ranging from 0 to 8) in which they engaged in light physical activity (LPA), moderate physical activity (MPA), and vigorous physical activity (VPA) during leisure time for at least 15 min. Based on the scoring guidelines (Godin, 2011), the three intensity levels of PA were based on the corresponding metabolic equivalents of Task (MET) values (3 MET, MPA = 5 MET, and VPA = 9 MET). Precisely, the PA intensity level was calculated as follows: LPA = frequency × 3 metabolic equivalents (MET), MPA = frequency × 5 MET, and VPA = frequency × 9 MET. The calculated scores for LPA (range, 0–24), MPA (range, 0–40), and VPA (range, 0–72) were used for data analysis.

6.2. BMI

Participants' height and weight were obtained through onsite measurements. During the data collection process, students were required to wear thinner clothes indoors and remove their shoes for measurement. BMI was calculated by dividing a person's weight in kilograms by the square of their height in meters (kg/m^2).

6.3. Other physical fitness items

The 800/1000 M, FB, SLJ, 50 M, and VC of participants were obtained through onsite measurements. The corresponding test scores (total score = 100 points) were calculated using the Shanghai Junior High School Physical Health Project Performance Evaluation Standards.

6.4. Data analysis technique

In this study, SmartPLS (PLS-SEM) software, version 4.0, was used to perform the structural equation modeling. The primary objective of this study was to explore the relationship between PA, BMI, and physical fitness (800/1000 M, FB, SLJ, 50 M, and VC). The final objective was to develop a framework of PA, BMI, and physical fitness for Shanghai junior high school students and to investigate the impact of different intensities PAs on different types of physical fitness through BMI.

7. Results

Table 1 explained on the demographic characteristics of respondents consists of gender and age. It showed the detailed of the demographic variables analysis result. Frequency and percentage were used to analyses the respondents' profiles. As show in the Table 1, among the samples, there are 198 males (53.2 % of the total samples) and 174 females (46.8 % of the total samples), the age of 14 were 166 students (44.6 % of the total samples), the age of 15 were 188 students (50.5 % of the total samples), the age of 16 were 30 students (4.8 % of the total samples).

Table 2
Model fit of physical activity, body mass index, and physical fitness among Shanghai junior high school students in 2023.

	Estimated model
SRMR	0.089
d_ULS	0.353
d_G	0.090
Chi-square	171.685
NFI	0.643

Table 3
Smart PLS-SEM results of physical activity, body mass index, and physical fitness among Shanghai junior high school students in 2023.

Hypothetical relationships	Beta (β) Beta (β)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
H1 = LPA −> BMI	0.047	0.052	0.913	0.361
H2 = MPA −> BMI	−0.106	0.054	1.961	0.050*
H3 = VPA −> BMI	0.134	0.057	2.353	0.019*
H4 = BMI −> 50 M	−0.301	0.061	4.963	0.000**
H5 = BMI −> 800/1000 M	−0.368	0.066	5.571	0.000**
H6 = BMI −> FB	0.068	0.047	1.458	0.145
H7 = BMI −> SLJ	−0.480	0.053	9.023	0.000**
H8 = BMI −> VC	0.279	0.048	5.812	0.000**
H9a = LPA −> 50 M	0.055	0.047	1.171	0.241
H9b = LPA −> 800/1000 M	0.015	0.046	0.322	0.748
H9c = LPA −> FB	0.037	0.050	0.732	0.464
H9d = LPA −> SLJ	0.027	0.047	0.563	0.573
H9e = LPA −> VC	0.005	0.050	0.099	0.922
H10a = MPA −> 50 M	0.118	0.049	2.426	0.015*
H10b = MPA −> 800/1000 M	0.106	0.056	1.899	0.058
H10c = MPA −> FB	0.140	0.057	2.472	0.013*
H10d = MPA −> SLJ	0.046	0.050	0.924	0.355
H10e = MPA −> VC	−0.011	0.057	0.185	0.853
H11a = VPA −> 50 M	0.155	0.048	3.255	0.001**
H11b = VPA −> 800/1000 M	0.105	0.059	1.779	0.075
H11c = VPA −> FB	−0.123	0.051	2.413	0.016*
H11d = VPA −> SLJ	0.072	0.047	1.533	0.125
H11e = VPA −> VC	0.010	0.064	0.151	0.880

Notes: * $p < 0.05$; ** $p < 0.01$, LPA = light physical activity, MPA = moderate physical activity, VPA = vigorous physical activity, BMI = body mass index, 800/1000 M = 800/100 m, FB = sitting forward bend, SLJ = standing long jump, 50 M = 50 m, VC = vital capacity.

As the questionnaire of PA was non-scale questionnaire, the data of BMI and physical fitness were getting through measurement, so the model contained only formative or single-item constructs and couldn't assess its reliability and validity through Fornell-Larcker and HTMT criterion. To use SEM, we first determined the fitness of the structural model (Table 2), the SRMR of presented model was less than 0.1 and it was acceptable.

As presented in Table 3, the results of H1 ($\beta = 0.047$, $t = 0.913$, $p = 0.361$), H9a ($\beta = 0.055$, $t = 1.171$, $p = 0.241$), H9b ($\beta = 0.015$, $t = 0.322$, $p = 0.748$), H9c ($\beta = 0.037$, $t = 0.732$, $p = 0.464$), H9d ($\beta = 0.027$, $t = 0.563$, $p = 0.573$), and H9e ($\beta = 0.005$, $t = 0.099$, $p = 0.922$) were all not supported—LPA did not influence BMI, 50 M, 800/1000 M, FB, SLJ, and VC. The results of H2 (β = -0.106, $t = 1.961$, $p = 0.05$), H10a ($\beta = 0.118$,

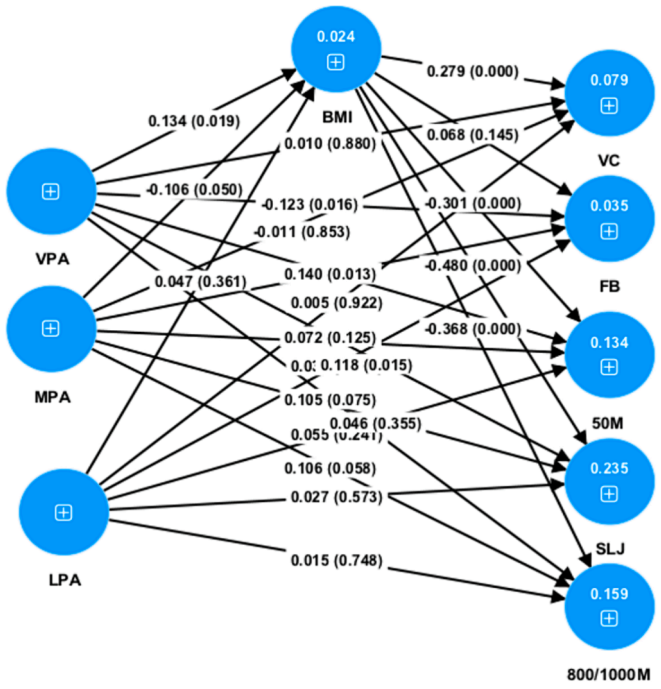

Fig. 2. PLS-SEM results of physical activity, body mass index, and physical fitness among Shanghai junior high school students in 2023.

$t = 2.426$, $p = 0.015$), H10c ($\beta = 0.14$, $t = 2.472$, $p = 0.013$) indicated that MPA had an influence on BMI, 50 M, and FB. However, because P values for H10b ($\beta = 0.106$, $t = 1.899$, $p = 0.058$), H10d ($\beta = 0.046$, $t = 0.924$, $p = 0.355$), and H10e (β = -0.011, $t = 0.185$, $p = 0.853$) were above 0.05, we concluded that MPA had no influence on 800/1000 M, SLJ and VC. The results of H11a ($\beta = 0.155$, $t = 3.255$, $p = 0.001$) indicated statistical significance at the 5 % level for VPA's positive effects on 50 M; the findings confirmed H11a, which asserted that VPA had a favorable impact on 50 M. The results of H3 ($\beta = 0.134$, $t = 2.353$, $p = 0.019$) and H11c (β = -0.123, $t = 2.413$, $p = 0.016$) indicated that VPA positively influenced BMI and FB. The results of H11b ($\beta = 0.105$, $t = 1.779$, $p = 0.075$), H11d ($\beta = 0.072$, $t = 1.533$, $p = 0.125$), H11e ($\beta = 0.01$, $t = 0.151$, $p = 0.88$) indicated that VPA had no influence on 800/1000 M, SLJ and VC (Fig. 2).

The results of H4 (β = -0.301, $t = 4.963$, $p = 0.000$), H5 (β = -0.368, $t = 5.571$, $p = 0.000$), H7 (β = -0.480, $t = 9.023$, $p = 0.000$), H8 ($\beta = 0.279$, $t = 5.812$, $p = 0.000$) indicated that BMI had positive influence on VC and had negative influence on 50 M, 800/1000 M and SLJ. However, the results of H6 ($\beta = 0.068$, $t = 1.458$, $p = 0.145$) indicated that BMI did not influence FB,

Furthermore, analysis of the total indirect path is as follows: VPA → SLJ (estimate = -0.064, $t = 2.019$, $p = 0.044$), VPA → VC (estimate = 0.037, $t = 2.094$, $p = 0.036$), and analysis of specific indirect effects revealed two significant indirect paths: VPA → BMI → SLJ (estimate = -0.064, $t = 2.019$, $p = 0.044$), VPA → BMI → VC (estimate = 0.037, $t = 2.094$, $p = 0.036$) (Table 2), because their P values were above 0.05, and thus, BMI mediated the relationship between VPA and SLJ; furthermore, BMI also mediated the relationship between VPA and VC as shown in the Table 4.

Table 4
Results of total and specific indirect effects of physical activity, body mass index, and physical fitness among Shanghai junior high school students in 2023.

Path	Standardized Estimate	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Total indirect effects				
LPA −> 50 M	−0.014	0.016	0.891	0.373
LPA −> 800/1000 M	−0.017	0.020	0.884	0.377
LPA −> FB	0.003	0.005	0.670	0.503
LPA −> SLJ	−0.023	0.025	0.917	0.359
LPA −> VC	0.013	0.015	0.877	0.380
MPA −> 50 M	0.032	0.018	1.800	0.072
MPA −> 800/1000 M	0.039	0.022	1.786	0.074
MPA −> FB	−0.007	0.007	1.098	0.272
MPA −> SLJ	0.051	0.026	1.935	0.053
MPA −> VC	−0.030	0.017	1.779	0.075
VPA −> 50 M	−0.040	0.022	1.813	0.070
VPA −> 800/1000 M	−0.049	0.025	1.941	0.052
VPA −> FB	0.009	0.008	1.155	0.248
VPA −> SLJ	−0.064	0.032	2.019	0.044*
VPA −> VC	0.037	0.018	2.094	0.036*
Specific indirect effects				
LPA −> BMI −> 800/1000 M	−0.017	0.020	0.884	0.377
MPA −> BMI −> VC	−0.030	0.017	1.779	0.075
MPA −> BMI −> 800/1000 M	0.039	0.022	1.786	0.074
VPA −> BMI −> FB	0.009	0.008	1.155	0.248
MPA −> BMI −> SLJ	0.051	0.026	1.935	0.053
MPA −> BMI −> 50 M	0.032	0.018	1.800	0.072
LPA −> BMI −> VC	0.013	0.015	0.877	0.380
LPA −> BMI −> 50 M	−0.014	0.016	0.891	0.373
VPA −> BMI −> VC	0.037	0.018	2.094	0.036*
LPA −> BMI −> FB	0.003	0.005	0.670	0.503
LPA −> BMI −> SLJ	−0.023	0.025	0.917	0.359
VPA −> BMI −> 50 M	−0.040	0.022	1.813	0.070
MPA −> BMI −> FB	−0.007	0.007	1.098	0.272
VPA −> BMI −> 800/1000 M	−0.049	0.025	1.941	0.052
VPA −> BMI −> SLJ	−0.064	0.032	2.019	0.044*

Notes: * $p < 0.05$; ** $p < 0.01$, LPA = light physical activity, MPA = moderate physical activity, VPA = vigorous physical activity, BMI = body mass index, 800/1000 M = 800/100 m, FB = sitting forward bend, SLJ = standing long jump, 50 M = 50 m, VC = vital capacity.

8. Conclusion

Firstly, in this study, LPA had no influence BMI, 50 M, 800/1000 M, FB, SLJ, or VC, proving that it is difficult for LPA to improve physical fitness and overweight and obesity rates of junior high school students.

Secondly, BMI emerged as a pivotal factor influencing physical fitness. It was found that higher BMI negatively impacted certain physical fitness components such as sprinting (50 m), endurance (800/1000 m), and lower body strength (SLJ), while positively influencing vital capacity (VC). This emphasized the importance of addressing BMI levels to enhance overall physical fitness in junior high school students.

Furthermore, MPA and VPA were found to have divergent effects on BMI. While MPA was associated with a reduction in BMI, VPA exhibited a positive correlation with BMI. Both MPA and VPA positively influenced certain physical fitness components such as sprinting (50 M) and flexibility (FB), albeit with differing impacts on other aspects of physical fitness.

Importantly, BMI was identified as a mediating factor in the

relationship between MPA/VPA and specific physical fitness indicators such as SLJ and VC. This underscored the complex interplay between BMI, physical activity levels, and physical fitness outcomes among junior high school students.

9. Implications

The findings suggested a need for tailored PA interventions and policies in junior high schools in Shanghai. Policymakers should consider implementing programs that encourage MVPA while addressing factors contributing to sedentary behaviors among students. Additionally, policies aimed at promoting healthy weight management strategies could be beneficial in improving overall physical fitness levels. Educators and physical education instructors play a crucial role in shaping students' attitudes and behaviors towards PA. They should incorporate evidence-based practices into physical education curricula that emphasize the importance of maintaining a healthy BMI and engaging in regular PA for improving physical fitness. Providing students with opportunities for both MVPA can have positive implications for their BMI and various physical fitness components.

Health professionals and practitioners should collaborate with schools to develop comprehensive health promotion strategies targeting both PA and BMI among junior high school students. These strategies could include providing nutrition education, promoting active commuting to school, and offering extracurricular PA programs that cater to students' diverse needs and preferences. Parents and caregivers play a crucial role in influencing children's behaviors related to PA and nutrition. They should be educated about the importance of encouraging their children to engage in regular physical activity and adopt healthy lifestyle habits from an early age. Schools can facilitate parental involvement by providing resources and workshops focused on promoting healthy behaviors at home.

CRediT authorship contribution statement

Dan Bai: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Asha Hasnimy Mohd Hashim:** Methodology, Formal analysis, Data curation, Conceptualization. **Yanna Li:** Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

We extend our gratitude to the Universiti Teknologi Malaysia (UTM) for their steadfast support throughout the preparation of this article.

Human Subjects Approval Statement

This study has been reviewed and approved by the ethics committee of Universiti Teknologi Malaysia (UTM).

References

Cai, Y., Zhu, X., Wu, X., 2017. Overweight, obesity, and screen-time viewing among Chinese school-aged children: National prevalence estimates from the 2016 Physical Activity and Fitness in China—The Youth Study. J. Sport Health Sci. 6 (4), 404–409. https://doi.org/10.1016/j.jshs.2017.09.002.

Carriedo, A., Cecchini, J.A., Fernández-Álvarez, L.E., González, C., 2022. Physical activity and physical fitness in adolescents after the COVID-19 lockdown and one year afterward. Int. J. Environ. Res. Public Health 19 (22). https://doi.org/10.3390/ijerph192214660.

Dasso, N.A., 2019. How is exercise different from physical activity? A concept analysis. Nursing Forum 54 (1), 45–52. https://doi.org/10.1111/nuf.12296.

Godin, G., 2011. The godin-shephard leisure-time physical activity questionnaire. Health Fitness J. 4 (1), 17–22.

Hills, A.P., Andersen, L.B., Byrne, N.M., 2011. Physical activity and obesity in children. Brit. J. Sports Med. 45 (11), 866–870. https://doi.org/10.1136/bjsports-2011-090199.

Jiang, J., Song, J., Li, C., 2020. Correlation between the time and complexity of high-intensity physical activity and physical health among junior high school students. Chin. Studies School Health 41 (2), 179–182.

Kumar, B., Robinson, R., & Till, S. (2015). *Physical activity behaviours and health risk*.

Li, H., Chen, P., Zhuang, J., 2011. Study on the correlation between physical activity status and physical health among adolescents in Shanghai. Shanghai J. Prevent. Med. 23 (4), 145–148.

Menhas, R., Dai, J., Ashraf, M.A., Noman, S.M., Khurshid, S., Mahmood, S., Weng, Y., Laar, R.A., Sang, X., Kamran, M., Shahzad, B., Iqbal, W., 2021. Physical inactivity, non-communicable diseases and national fitness plan of China for physical activity. Risk Manage. Healthcare Policy 14, 2319–2331. https://doi.org/10.2147/RMHP.S258660.

Navarro, J.L., Tudge, J.R.H., 2023. Technologizing bronfenbrenner: neo-ecological theory. Curr. Psychol. 42 (22), 19338–19354. https://doi.org/10.1007/s12144-022-02738-3.

Physical Activity Facts. (2022, July 26). Chronic Disease Prevention and Health Promotion. https://www.cdc.gov/healthyschools/physicalactivity/facts.htm.

Results of the 2014 National Student Physical Health Survey. (2015). *Chinese School Health*, *36*(12), 4.

Saqib, Z.A., Dai, J., Menhas, R., Mahmood, S., Karim, M., Sang, X., Weng, Y., 2020. Physical activity is a medicine for non-communicable diseases: A survey study regarding the perception of physical activity impact on health wellbeing. Risk Manage. Healthcare Policy 13, 2949–2962. https://doi.org/10.2147/RMHP.S280339.

Siscovick, D.S., Laporte, R.E., Newman, J., Health, Iverson, D.C., Fielding, J.E., 1985. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research synopsis. Public Health Rep. 100.

Södergren, M., Sundquist, J., Johansson, S.E., Sundquist, K., 2008. Physical activity, exercise and self-rated health: A population-based study from Sweden. BMC Public Health 8. https://doi.org/10.1186/1471-2458-8-352.

Staunton, S., Naidu, R., 2023. Ecological Theory. Encyclopedia of Soils in the Environment 15–21. https://doi.org/10.1016/B978-0-12-822974-3.00256-1.

van Sluijs, E. M. F., Ekelund, U., Crochemore-Silva, I., Guthold, R., Ha, A., Lubans, D., Oyeyemi, A. L., Ding, D., & Katzmarzyk, P. T. (2021). Physical activity behaviours in adolescence: current evidence and opportunities for intervention. In *The Lancet* (Vol. 398, Issue 10298, pp. 429–442). Elsevier B.V. https://doi.org/10.1016/S0140-6736(21)01259-9.

Wang, X., Hui, Z., Terry, P.D., Ma, M., Cheng, L., Deng, F., Gu, W., Zhang, B., 2016. Correlates of insufficient physical activity among junior high school students: A cross-sectional study in Xi'an, China. Internat. J. Environ. Res. Public Health 13 (4). https://doi.org/10.3390/ijerph13040397.

Wang, Z., Li, K., Guo, S., Wen, X., He, Z., Cai, Y., 2023. Can moving more and sitting less improve the academic engagement of adolescents?-A study based on junior high school students in Shanghai, China. Psychol. Res. Behav. Manag. 16, 4155–4168. https://doi.org/10.2147/PRBM.S427214.

Wyszyńska, J., Ring-Dimitriou, S., Thivel, D., Weghuber, D., Hadjipanayis, A., Grossman, Z., Ross-Russell, R., Dereń, K., Mazur, A., 2020. Physical activity in the prevention of childhood obesity: the position of the European Childhood Obesity Group and the European Academy of Pediatrics. Front. Pediatrics 8. https://doi.org/10.3389/fped.2020.535705.

Yang, M., Sun, J., Yan, G., 2018. Relationship between body mass index and physical fitness of students aged 7 to 18. Chin. School Health 39 (5), 4.

Zhang, J., Tang, Y., Hu, Y., Liu, Y., 2016. International comparison of physical activity among children and adolescents based on human development index. Sports Sci. 36 (10), 3–11.

Zhao, B., Kong, Z., Li, H., 2022. The relationship between body composition and physical fitness of children and adolescents. China School Health 43 (1), 5.

Zhu, Z., Yang, Y., Kong, Z., Zhang, Y., Zhuang, J., 2017. Prevalence of physical fitness in Chinese school-aged children: Findings from the 2016 Physical Activity and Fitness in China—The Youth Study. J. Sport Health Sci. 6 (4), 395–403. https://doi.org/10.1016/j.jshs.2017.09.003.