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Associations of moderate-to-vigorous physical activity and body roundness index with psychological symptoms in adolescents in mainland China: a national multicenter cross-sectional survey

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Abstract

Background Decreased physical activity and overnutrition among adolescents have become important public health problems shared by countries around the world. In addition, the prevalence of psychological symptoms among adolescents continues to increase, which negatively affects schooling and future quality of life. However, no studies have been found in the past on the association of moderate-to-vigorous physical activity(MVPA) and body roundness index(BRI) with psychological symptoms in Chinese adolescents. This study may provide theoretical support for the prevention and intervention of psychological symptoms among adolescents in mainland China.

Methods From September to November 2023, MVPA, BRI, and psychological symptoms were assessed in 43,031 adolescents aged 12–17 years from different regions of mainland China. The chi-square test, t-test, logistic regression analysis, and ordered logistic regression were used to analyze the associations that existed between MVPA and BRI with psychological symptoms.

Results The prevalence of psychological symptoms among adolescents in mainland China was 20.3%. The proportions of adolescents with MVPA of < 30 min/day, 30–60 min/day, and > 60 min/day were 46.0%, 40.0%, and 14.0%, respectively. The adolescent BRI value was (2.02 ± 0.95); boys (2.12 ± 1.03) had a higher BRI value than girls (1.92 ± 0.86), and the difference was statistically significant ($t = 22.111$, $P < 0.001$). After adjusting for relevant covariates, ordered logistic regression analysis showed that, overall, adolescents in the group with MVPA > 60 min/day and BRI quartiles Q1 as the reference group, adolescents in the group with MVPA of 30–60 min/day and BRI quartiles Q2 (OR = 0.65, 95% CI:0.51 ~ 0.82) had a lower risk of developing psychological symptoms ($P < 0.001$); adolescents in the MVPA < 30 min/day group and BRI quartiles Q4 group (OR = 1.62, 95% CI: 1.30–2.02) had a higher risk of psychological symptoms ($P < 0.001$).

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Conclusions There is an association between MVPA and BRI and psychological symptoms among adolescents in mainland China. A decrease in MVPA and an increase in BRI were associated with an increase in the prevalence of psychological symptoms. In the future, we should effectively improve the MVPA level and maintain a reasonable BRI value in adolescents in mainland China to better promote adolescents' mental health development.

Clinical trial number Not applicable.

Keywords Moderate-to-vigorous physical activity, Body roundness index, Psychological symptoms, China, Cross-sectional survey

Introduction

In recent years, the prevalence of psychological symptoms among adolescents is showing a continuously rising trend with the great lifestyle changes, which brings a serious medical burden to society [1]. A survey showed that the prevalence of psychological symptoms among adolescents was as high as 29% and showed a continuing trend of increase, and called for the necessary measures to be taken to curb it [2]. Surveys have also shown that the prevalence of depressive symptoms among U.S. adolescents has risen from 3.1% in 2016 to 4.0% in 2020, an increase of approximately 30%; anxiety symptoms in this group have risen from 7.1% in 2016 to 9.2% in 2020 and show a continuing trend of increase, which has a serious negative impact on adolescents' physical and mental health [3]. China is no exception. Surveys show that the prevalence of psychological symptoms among Chinese adolescents has reached 21.4%, and shows a continuous upward trend [4]. As a result, the problem of adolescent psychological symptoms is becoming more and more serious and should be given attention and concern. Studies have found that the occurrence of psychological symptoms in adolescence hurts academic performance, and there is a significant trajectory effect of this negative impact, which also hurts mental health in adulthood, so the prevention of psychological symptoms in adolescence is particularly important [5, 6]. In addition, studies have found that there is a strong link between the occurrence of various psychological problems in adulthood and the health status of adolescents, which suggests that the development of mental health in adolescence is of great practical significance to the healthy development of the entire life cycle [7, 8]. However, previous research on adolescent psychosocial symptoms is very limited. In particular, fewer studies have been conducted on adolescent psychological symptoms in developing countries. The increased prevalence of psychological symptoms in adolescents is influenced by a combination of factors, mainly related to lifestyle and exercise habits [9, 10].

The survey showed that among the various factors affecting adolescents' psychological symptoms, the level of physical activity was particularly important in influencing adolescents' psychological symptoms [11–13]. The study found that adolescents with low levels of physical activity had a significantly higher risk of depression and anxiety compared to those with high levels of physical activity [14, 15]. Multiple studies have found that in terms of physical activity affecting psychological symptoms, their moderate-to-vigorous physical activity(MVPA) hours have a particularly pronounced effect on adolescent psychological symptoms [16, 17]. In addition, a survey of adolescents also found a significant negative association between adolescent MVPA hours and psychological symptoms [18]. However, previous studies have focused more on adolescent populations in developed countries, and research on adolescents in developing countries is relatively limited. The only studies that have found an association between physical activity duration and psychological symptoms among Chinese adolescents have found that adolescents who exercise longer have a lower risk of developing psychological symptoms [19]. Taken together, these various studies have found a strong association between MVPA and psychological symptoms in adolescents. It has also been found that adolescent psychological symptoms are associated with body composition or obesity, in addition to physical activity [20].

Body roundness index(BRI) as a new indicator of body fatness, can more accurately reflect the body fat content of adolescents compared with the traditional body mass index(BMI) [21]. The study found that BRI has a higher sensitivity for evaluating people's risk of all-cause mortality, chronic disease, and diabetes compared to BMI [22]. It has also been found that BRI is more effective in evaluating mental health than waist circumference, BMI, and a body shape index (ABSI) indicators [23]. It can be seen that the BRI can better assess adolescents' mental health. It is worth noting that through the literature, it is found that the past studies on the association between BRI and psychological symptoms in Chinese adolescents are very limited. For this reason, it is necessary to investigate the association between BRI and psychological symptoms in Chinese adolescents to better recognize the occurrence of psychological symptoms in adolescents.

Past literature has shown that most studies have focused on the effects of a single physical activity or BRI with psychological symptoms, and these studies have focused on adult populations, with relatively few studies

on adolescent populations [23, 24]. In addition, no studies have been conducted on the relationship between MVPA and BRI and psychological symptoms in adolescents. Adolescents are at the peak of their adolescent development, which is extremely unstable and prone to various psychological problems. Therefore, analyzing the causes of common psychological symptoms in adolescents can better prevent the occurrence of psychological symptoms and improve the quality of healthy life. To this end, the present study assessed MVPA, BRI, and psychological symptoms among 43,031 adolescents aged 12–17 years from five regions in mainland China, to analyze the associations between them. This study aims to provide theoretical support for the prevention and intervention of psychological symptoms among adolescents in mainland China.

Methods

Participants

From September to November 2023, based on the distribution of different provinces in mainland China, considering different regions in east, west, south, and north, this study was divided into four phases for the extraction of participants. First, Harbin, Guangzhou, Shanghai, Xinjiang, and Henan in the north, south, east, west, and center of China were selected as the regions from which the participants of this study were extracted. Second, one city in each region was selected, Changchun, Guangzhou, Shanghai, Urumqi, and Zhengzhou as the sampling cities for the participants of this study. Third, eight middle schools were selected in each city as the sampling schools for the participants of this study. Fourth, four teaching classes were randomly selected from all classes in each grade in each school, and the eligible students in the classes were the participants of this study. The specific inclusion criteria were: middle and high school students enrolled in school; age range of 12–17 years old; voluntary assessment for this study and written informed consent from parents. Finally, a total of 44,814 adolescents aged 12–17 years old from 960 instructional classes were selected as participants of this study and were assessed for MVPA, BRI, and psychological symptoms. After the assessment, a total of 43,031 valid questionnaires were returned after excluding 1,783 invalid questionnaires with broken questionnaires, missing key demographic information, and response rates lower than 80%, resulting in a valid return rate of 96.02%. This study was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from parents or guardians prior to the assessment of participants in this study, and participants volunteered to be assessed for this study. Approved by the Human Ethics Committee of Chizhou University (2023874592). Figure 1 shows the regional distribution of participant sampling among adolescents in mainland China. Figure 2 shows the sampling process of participants in this study.

Psychological symptoms assessment

In this study, the Multidimensional Sub-health Questionnaire of Adolescents (MSQA) questionnaire was used to assess the psychological symptoms of adolescents in mainland China [25]. MSQA questionnaire is widely used among Chinese adolescents [26, 27]. It has good reliability and validity for assessing the psychological symptoms of Chinese adolescents. The Cronbach's α coefficient of the scale was 0.957 [28]. The questionnaire consists of 39 entries and focuses on the psychological changes of the participants in the last six months. The questionnaire consists of three dimensions: emotional problems, behavioral problems, and social adjustment difficulties. The presence or absence of psychological symptoms was assessed based on the final total score of the questionnaire. Each entry was rated on a 6-point scale ranging from"lasting 3 months or more" to "none or less than 1 week". A score of 1 was recorded when the participant chose "lasted 1 month" or more, participants scored 0 when they chose "lasted less than 1 month" or less. When a participant scored ≥ 3 on the assessment, he or she had emotional problems. A score of ≥ 4 indicates the presence of behavioral problems. When the participant assessment score was ≥ 8, it indicated the presence of social adjustment difficulties. A total score of ≥ 8 on the participant assessment indicated the presence of psychological symptoms. Higher scores indicated that participants had more severe psychological symptoms.

Moderate-to-vigorous physical activity

In this study, the MVPA of adolescents was assessed using the Adolescent Physical Activity Questionnaire in the Guidelines for Evaluating the Physical Activity Levels of Children and Adolescents Between the Ages of 7 and 18 Years, published by the National Bureau of Disease Control and Prevention of China (WS/T 10008 – 2023) [29]. The assessment questionnaire is the standard of the health industry in the People's Republic of China and is a nationally recognized assessment questionnaire for assessing physical activity in adolescents in China. The questionnaire consists of 27 different physical activity items and sports, such as running, stair climbing, housework, soccer, basketball, and badminton. Participants filled in the average duration, frequency, and specific intensity of each physical activity program according to their actual situation in the past 1 week. The intensity of the activity was categorized as "easy", "a little tired", and "very tired" according to the participants' feelings. Based on the different intensities chosen by the participants, the average length of MVPA in the past week was calculated. This questionnaire is widely used among Chinese

Fig. 1 Distribution of sampling regions of adolescent participants in mainland China

adolescents. The correlation between this questionnaire and MVPA status measured by the accelerometer was 0.689, which has good reliability and validity. In this study, MVPA was categorized based on the participants' actual conditions and combined with several previous studies [30, 31]. The MVPA of participants in this study was categorized as < 30 min/day, 30–60 min/day, and > 60 min/day.

Body roundness index(BRI)

BRI was originally proposed by Thomas et al. [32]. BRI as a predictor of visceral adipose tissue and body fat percentage in response to human adiposity has been demonstrated in several studies and different populations [21, 33]. The BRI was calculated from the participants' height and waist circumference assessments. The specific BRI calculation formula was: $364.2\text{-}365.5 \times (1\text{-}[WC(m)/2\pi]^2/[0.5\times height(m)]^2)½$ [32]. Participants' height and waist circumference were assessed according to the testing methods and instruments required by the China National Survey on Students' Constitution and Health (CNSSCH) [34]. Height is accurate to 0.1 centimeters. Waist circumference is also accurate to 0.1 centimeters. Waist circumference was assessed by asking participants to wear as light clothing as possible for the test to guarantee the accuracy of the results. Height was assessed by asking participants to remove their shoes. In the analysis of this study, after stratifying the participants based on their age and gender, the BRI was divided into 4 groups (Q1, Q2, Q3, and Q4), according to quartiles.

Covariates

The covariates in this study included family economic income, sleep duration, snack consumption, height, weight, standing long jump, and 50-meter dash. Family economic income mainly assessed the average income level of participants' families in the past 1 month, which was categorized in this study as < 3000 yuan/month、3001–5000 yuan/month、5001–8000 yuan/month、>8000 yuan/month [35]. Sleep duration was calculated based on the participants' time of going to sleep and time of waking up in the past 1 week, and the participants' average daily sleep duration in the past week was assessed. This study was categorized according to the classification criteria of previous studies into <7 h/day, 7–9 h/day, >9 h/day [36]. Snack consumption primarily assessed how often participants used breakfast in the past 7 days, which was categorized in this study as < 1 times/week, 2–4 times/week, and > 4 times/week.

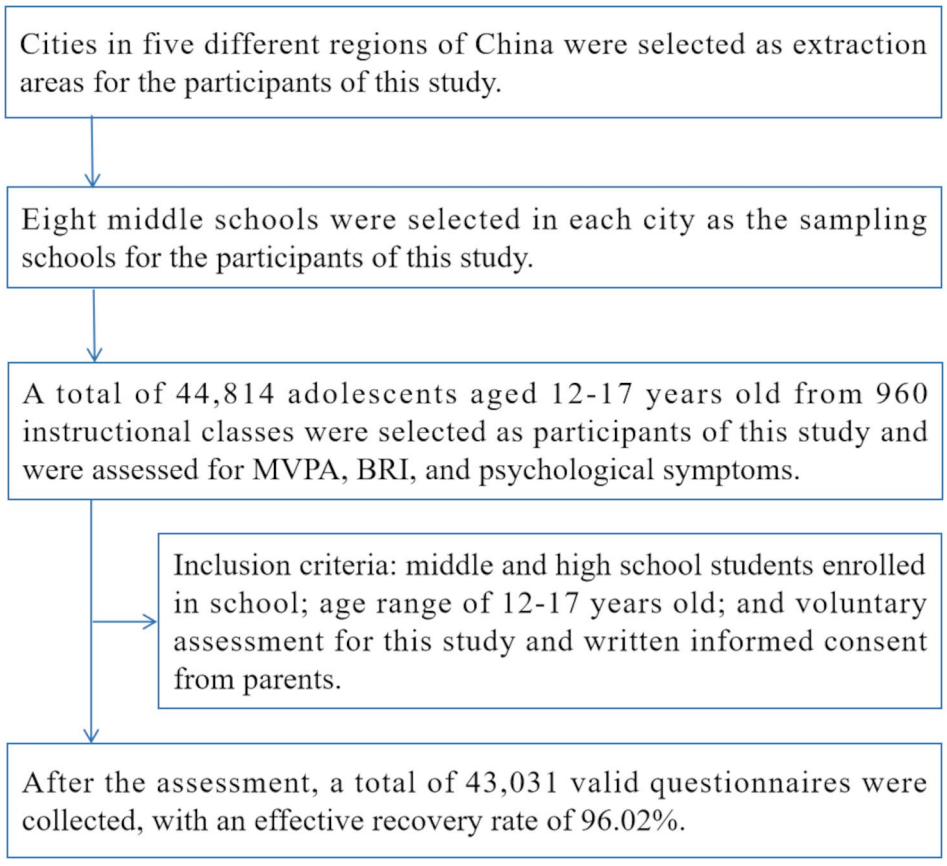

Fig. 2 Sampling flow of adolescent participants in mainland China

Statistical analysis

Continuous variables in this study were expressed as mean and standard deviation (M ± SD). Categorical variables were expressed as percentages. Comparisons of continuous variables by gender or the presence of psychological symptoms were performed using the t-test. Comparisons of categorical variables were performed using the chi-square test. The associations of MVPA and BRI with psychological symptoms in adolescents in this study were analyzed using binary logistic regression analysis and ordered logistic regression analysis. Regression analysis was conducted with the presence of psychological symptoms in adolescents as the dependent variable and MVPA and BRI as the independent variables. In the binary logistic regression analysis, Model 2 adjusts for age and family economic income in addition to Model (1) Model 3 adjusts for sleep duration, snack consumption, standing long jump, and 50-meter run in addition to Model (2) In ordered logistic regression analysis, the model adjusted for age and family economic income, sleep duration, snack consumption, standing long jump, and 50-meter run. The dose-relationship curves of the physical activity and body roundness index with the psychological symptoms were drawn using a restricted cubic spline regression model. Graphs show ORs for psychological symptoms according to BRI and MVPA adjusted for age, family economic income, sleep duration, snack consumption, standing long jump, and 50-meter run. Data were fitted by a logistic regression model with 3 knots at the 10th, 50th, 90th percentiles of BRI and MVPA (reference is the median). Solid lines indicate ORs, and shadow shape indicate 95% CIs. The study was analyzed using SPSS 25.0 software and R software (version 4.4.04, R Development Core Team). $P < 0.05$ was used as a two-sided test level.

Results

Table 1 shows the basic characteristics of Chinese adolescent participants. In this study, MVPA, BRI, and psychological symptoms were assessed in 43,031 (21,498 boys, 49.96%) adolescents aged 12–17 years in mainland China. The mean age of the participants was (14.69 ± 1.62) years. The results of this study showed that the prevalence of psychological symptoms among adolescents in mainland China was 20.3%. The prevalence of adolescents' emotional problems, behavioral problems, and social adjustment difficulties was 27.5%, 26.7%, and 17.0%, respectively. The proportions of Chinese adolescents with

Table 1 Basic characteristics of Chinese youth participants

Variables	Total	Boys	Girls	χ^2/t-value	*P*-value
Number	43,031	21,498(49.96)	21,533(50.04)		
Age (years)	14.69 ± 1.62	14.64 ± 1.62	14.73 ± 1.63	-5.454	<0.001
Family economic income					
< 3000 yuan/month	4710(10.9)	2256(10.5)	2454(11.4)	177.773	<0.001
3001–5000 yuan/month	15,423(35.8)	7238(33.7)	8185(38.0)		
5001–8000 yuan/month	12,934(30.1)	6496(30.2)	6438(29.9)		
>8000 yuan/month	9964(23.2)	5508(25.6)	4456(20.7)		
Sleep duration					
<7 h/day	6880(16.0)	3306(15.4)	3574(16.6)	87.815	<0.001
7–9 h/day	29,894(69.5)	14,730(68.5)	15,164(70.4)		
>9 h/day	6257(14.5)	3462(16.1)	2795(13.0)		
Snack consumption					
<1 times/week	7421(17.2)	4503(20.9)	2918(13.6)	557.795	<0.001
2–4 times/week	24,237(56.3)	12,098(56.3)	12,139(56.4)		
>4 times/week	11,373(26.4)	4897(22.8)	6476(30.1)		
MVPA					
<30 min/day	19,774(46.0)	8172(38.0)	11,602(53.9)	1391.408	<0.001
30–60 min/day	17,215(40.0)	9284(43.2)	7931(36.8)		
>60 min/day	6042(14.0)	4042(18.8)	2000(9.3)		
BRI quartiles					
Q1	11,124(25.9)	5143(23.9)	5981(27.8)	355.118	<0.001
Q2	10,756(25.0)	5028(23.4)	5728(26.6)		
Q3	10,531(24.5)	5210(24.2)	5321(24.7)		
Q4	10,620(24.7)	6117(28.5)	4503(20.9)		
Height(cm)	165.17 ± 8.95	169.33 ± 9.19	161.01 ± 6.41	108.885	<0.001
Weight(kg)	55.12 ± 12.10	58.94 ± 13.39	51.30 ± 9.19	69.035	<0.001
BMI(kg/m^2)	20.08 ± 3.45	20.42 ± 3.70	19.75 ± 3.15	20.142	<0.001
Waist circumference(cm)	69.09 ± 10.59	71.81 ± 11.31	66.37 ± 9.02	55.239	<0.001
Standing long jump(cm)	186.90 ± 33.18	205.75 ± 32.2	168.08 ± 21.36	143.028	<0.001
50-meter dash(s)	8.53 ± 1.19	7.94 ± 1.05	9.12 ± 1.03	-117.491	<0.001
BRI	2.02 ± 0.95	2.12 ± 1.03	1.92 ± 0.86	22.111	<0.001
Emotional problems	11,822(27.5)	5848(27.2)	5974(27.7)	1.580	0.209
Behavioral problems	11,486(26.7)	5947(27.7)	5539(25.7)	20.686	<0.001
Social adjustment difficulties	7303(17.0)	3806(17.7)	3497(16.2)	16.358	<0.001
Psychological symptoms	8723(20.3)	4415(20.5)	4308(20.0)	1.872	0.171

Note: "( )" is the percentage %. N, numbers; M, Mean; SD, standard deviation; MVPA, moderate-to-vigorous physical activity; BMI, Body mass index; BRI, body roundness index

MVPA of < 30 min/day, 30–60 min/day, and > 60 min/day were 46.0%, 40.0%, and 14.0%, respectively. The difference in MVPA distribution by sex was statistically significant (χ^2 value of 1391.408, $P < 0.001$). The BRI value for Chinese adolescents was (2.02 ± 0.95). In terms of sex, boys (2.12 ± 1.03) had higher BRI values than girls (1.92 ± 0.86), and the difference was statistically significant ($t = 22.111$, $P < 0.001$).

Table 2 shows the comparison of the prevalence of psychological symptoms among Chinese adolescent participants. The results of this study showed statistically significant differences in the prevalence of psychological symptoms among adolescents when comparing groups based on family economic income, sleep duration, snack consumption, MVPA, and BRI quartiles (χ^2 values were 124.027, 746.663, 228.699, 269.774, and 136.738, respectively, $P < 0.001$). Overall, adolescents with the presence of psychological symptoms had higher weight, BMI, waist circumference, and BRI than those without psychological symptoms. Meanwhile, adolescents with psychological symptoms had lower standing long jump and 50-meter dash scores than adolescents without psychological symptoms. ANOVA showed that *P* for trend < 0.01 for MVPA and BRI.

Table 3 shows the comparison of MVPA and BRI with psychological symptoms and the prevalence of each dimension in Chinese adolescents. Overall, the results showed that the differences in the prevalence of emotional problems, behavioral problems, social adjustment difficulties, and psychological symptoms among Chinese

Table 2 Comparison of prevalence of psychological symptoms among Chinese adolescent participants

Variables	Psychological symptoms		χ^2 /t-value	*P*-value
	Absent	Present		
Number	34,308(79.7)	8723(20.3)		
Age (years)	14.67 ± 1.64	14.76 ± 1.57	-4.712	<0.001
Sex			1.872	0.171
Boys	17,083(49.8)	4415(50.6)		
Girls	17,225(50.2)	4308(49.4)		
Family economic income			124.027	<0.001
< 3000 yuan/month	3474(10.1)	1236(14.2)		
3001–5000 yuan/month	12,351(36.0)	3072(35.2)		
5001–8000 yuan/month	10,508(30.6)	2426(27.8)		
>8000 yuan/month	7975(23.2)	1989(22.8)		
Sleep duration			746.663	<0.001
<7 h/day	4685(13.7)	2195(25.2)		
7–9 h/day	24,270(70.7)	5624(64.5)		
>9 h/day	5353(15.6)	904(10.4)		
Snack consumption			228.699	<0.001
<1 times/week	6012(17.5)	1409(16.2)		
2–4 times/week	19,783(57.7)	4454(51.1)		
>4 times/week	8513(24.8)	2860(32.8)		
MVPA			269.774	<0.001
<30 min/day	15,083(44.0)	4691(53.8)		
30–60 min/day	14,238(41.5)	2977(34.1)		
>60 min/day	4987(14.5)	1055(12.1)		
BRI quartiles			136.738	<0.001
Q1	9109(26.6)	2015(23.1)		
Q2	8711(25.4)	2045(23.4)		
Q3	8422(24.5)	2109(24.2)		
Q4	8066(23.5)	2554(29.3)		
Height(cm)	165.06 ± 8.94	165.57 ± 8.95	-4.748	<0.001
Weight(kg)	54.78 ± 11.87	56.44 ± 12.91	-11.438	<0.001
BMI(kg/m^2)	19.99 ± 3.37	20.47 ± 3.75	-11.632	<0.001
Waist circumference(cm)	68.78 ± 10.22	70.31 ± 11.86	-12.065	<0.001
Standing long jump(cm)	187.14 ± 33.04	185.97 ± 33.72	2.922	0.003
50-meter dash(s)	8.52 ± 1.18	8.56 ± 1.25	-2.847	0.004
BRI	1.99 ± 0.91	2.14 ± 1.11	-12.892	<0.001

Note:"( )" is the percentage %. N, numbers; M, Mean; SD, standard deviation; MVPA, moderate-to-vigorous physical activity; BMI, Body mass index; BRI, body roundness index

adolescents with different MVPAs were all statistically significant (χ^2 values were 329.047, 126.351, 280.638, and 269.774, $P<0.001$). In terms of different BRI quartiles, the prevalence of emotional problems, behavioral problems, social adjustment difficulties, and psychological symptoms in adolescents were also statistically significant when compared to each other (χ^2 values were 83.978, 86.119, 59.499, and 136.738, $P<0.001$). Overall, the prevalence was higher in adolescents with MVPA of < 30 min/d. The prevalence was also higher in adolescents with BRI quartiles in the Q4 group. The same trend was observed in boys and girls.

Table 4 shows the logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents. In this study, binary logistic regression analyses were conducted with the presence of psychological symptoms as the dependent variable and MVPA and BRI quartiles as the independent variables in Chinese adolescents, respectively. Overall, the analyses showed that adolescents in the MVPA < 30 min/day group (OR = 1.28, 95% CI: 1.19–1.38) were at increased risk for psychological symptoms ($P<0.001$), using the MVPA > 60 min/day group as the reference group. Using the BRI quartiles Q1 group as the reference group, adolescents in the BRI quartiles Q3 (OR = 1.15, 95% CI: 1.07–1.23) and Q4 (OR = 1.47, 95% CI: 1.37–1.57) groups also had a significantly higher risk of developing psychological symptoms ($P<0.001$). The same trend was observed in boys and girls.

Table 3 Comparison of MVPA and BRI with psychological symptoms and prevalence of each dimension in Chinese adolescents

Group/Sex	*N*	Emotional problems			Behavioral problems			Social adjustment difficulties			Psychological symptoms		
		N (%)	χ^2-value	*P*-value	*N* (%)	χ^2-value	*P*-value	*N* (%)	χ^2-value	*P*-value	*N* (%)	χ^2-value	*P*-value
Boys													
MVPA			198.968	<0.001		86.284	<0.001		197.839	<0.001		159.477	<0.001
<30 min/day	8172	2669(32.7)			2555(31.3)			1827(22.4)			2040(25.0)		
30–60 min/day	9284	2234(24.1)			2342(25.2)			1407(15.2)			1678(18.1)		
>60 min/day	4042	945(23.40)			1050(26.0)			572(14.2)			697(17.2)		
BRI quartiles			21.803	<0.001		17.594	0.001		11.35	0.01		58.783	<0.001
Q1	5143	1430(27.8)			1413(27.5)			961(18.7)			903(17.6)		
Q2	5028	1283(25.5)			1346(26.8)			843(16.8)			1011(20.1)		
Q3	5210	1359(26.1)			1377(26.4)			876(16.8)			1071(20.6)		
Q4	6117	1776(29.0)			1811(29.6)			1126(18.4)			1430(23.4)		
Girls													
MVPA			135.477	<0.001		60.955	<0.001		118.701	<0.001		129.360	<0.001
<30 min/day	11,602	3600(31.0)			3234(27.9)			2178(18.8)			2651(22.8)		
30–60 min/day	7931	1897(23.9)			1838(23.2)			1058(13.3)			1299(16.4)		
>60 min/day	2000	477(23.8)			467(23.4)			261(13.1)			358(17.9)		
BRI quartiles			76.498	<0.001		80.495	<0.001		63.137	<0.001		91.051	<0.001
Q1	5981	1678(28.1)			1580(26.4)			995(16.6)			1112(18.6)		
Q2	5728	1398(24.4)			1284(22.4)			809(14.1)			1034(18.1)		
Q3	5321	1450(27.3)			1322(24.8)			807(15.2)			1038(19.5)		
Q4	4503	1448(32.2)			1353(30.0)			886(19.7)			1124(25.0)		
Total													
MVPA			329.047	<0.001		126.351	<0.001		280.638	<0.001		269.774	<0.001
<30 min/day	19,774	6269(31.7)			5789(29.3)			4005(20.3)			4691(23.7)		
30–60 min/day	17,215	4131(24.0)			4180(24.3)			2465(14.3)			2977(17.3)		
>60 min/day	6042	1422(23.5)			1517(25.1)			833(13.8)			1055(17.5)		
BRI quartiles			83.978	<0.001		86.119	<0.001		59.499	<0.001		136.738	<0.001
Q1	11,124	3108(27.9)			2993(26.9)			1956(17.6)			2015(18.1)		
Q2	10,756	2681(24.9)			2630(24.5)			1652(15.4)			2045(19.0)		
Q3	10,531	2809(26.7)			2699(25.6)			1683(16.0)			2109(20.0)		
Q4	10,620	3224(30.4)			3164(29.8)			2012(18.9)			2554(24.0)		

Note:"( )" is the percentage %. N, numbers; MVPA, moderate-to-vigorous physical activity; BRI, body roundness index

Table 4 Logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents

Sex/Variable	Group	Psychological symptoms					
		Model 1		Model 2		Model 3	
		OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Boys							
MVPA	>60 min/day	1.00		1.00		1.00	
	30–60 min/day	1.06(0.96 ~ 1.17)	0.250	1.05(0.95 ~ 1.15)	0.373	0.99(0.90 ~ 1.09)	0.862
	<30 min/day	1.60(1.45 ~ 1.76)	<0.001	1.56(1.41 ~ 1.72)	<0.001	1.40(1.27 ~ 1.54)	<0.001
BRI quartiles	Q1	1.00		1.00		1.00	
	Q2	1.18(1.07 ~ 1.31)	0.001	1.18(1.07 ~ 1.31)	0.001	1.21(1.09 ~ 1.34)	<0.001
	Q3	1.22(1.10 ~ 1.34)	<0.001	1.21(1.10 ~ 1.34)	<0.001	1.24(1.12 ~ 1.37)	<0.001
	Q4	1.43(1.31 ~ 1.57)	<0.001	1.45(1.33 ~ 1.6)	<0.001	1.43(1.30 ~ 1.57)	<0.001
Girls							
MVPA	>60 min/day	1.00		1.00		1.00	
	30–60 min/day	0.90(0.79 ~ 1.02)	0.103	0.89(0.78 ~ 1.01)	0.065	0.85(0.74 ~ 0.96)	0.011
	<30 min/day	1.36(1.20 ~ 1.54)	<0.001	1.33(1.18 ~ 1.51)	<0.001	1.17(1.03 ~ 1.33)	0.015
BRI quartiles	Q1	1.00		1.00		1.00	
	Q2	0.97(0.88 ~ 1.06)	0.450	0.96(0.88 ~ 1.06)	0.409	0.97(0.88 ~ 1.07)	0.536
	Q3	1.06(0.97 ~ 1.17)	0.216	1.06(0.96 ~ 1.16)	0.244	1.06(0.97 ~ 1.17)	0.206
	Q4	1.46(1.33 ~ 1.60)	<0.001	1.45(1.32 ~ 1.60)	<0.001	1.44(1.31 ~ 1.58)	<0.001
Total							
MVPA	>60 min/day	1.00		1.00		1.00	
	30–60 min/day	0.99(0.92 ~ 1.07)	0.767	0.98(0.90 ~ 1.06)	0.541	0.93(0.86 ~ 1.01)	0.080
	<30 min/day	1.47(1.37 ~ 1.58)	<0.001	1.44(1.33 ~ 1.55)	<0.001	1.28(1.19 ~ 1.38)	<0.001
BRI quartiles	Q1	1.00		1.00		1.00	
	Q2	1.06(0.99 ~ 1.14)	0.087	1.06(0.99 ~ 1.13)	0.101	1.07(1.00 ~ 1.15)	0.051
	Q3	1.13(1.06 ~ 1.21)	<0.001	1.13(1.06 ~ 1.21)	<0.001	1.15(1.07 ~ 1.23)	<0.001
	Q4	1.43(1.34 ~ 1.53)	<0.001	1.44(1.35 ~ 1.54)	<0.001	1.47(1.37 ~ 1.57)	<0.001

Note: MVPA, moderate-to-vigorous physical activity; BRI, body roundness index; OR, Odds Ratio; 95% CI, 95% Confidence Interval. Model 1 is the crude model, Model 2 adjusts age and family economic income based on Model 1, and Model 3 adjusts sleep duration, snack consumption, standing long jump, and 50-meter run based on Model 2

Figure 3 shows the trend of ORs for binary logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents. Overall, as the duration of MVPA decreased, the risk of adolescents developing psychological symptoms increased. Similarly, as BRI increased, the risk of adolescents developing psychological symptoms increased, i.e., the OR values increased and shifted more to the right.

Table 5 shows the ordered logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents. In this study, ordered logistic regression analysis was conducted with the presence of psychological symptoms as the dependent variable and MVPA and BRI as the independent variables in Chinese adolescents. Overall the results of the analysis showed that with the MVPA > 60 min/day group and the BRI quartiles Q1 group as the reference group. Adolescents in the group with MVPA of 30–60 min/day and BRI quartiles Q2 (OR = 0.65, 95% CI: 0.51–0.82) had a lower risk of psychological symptoms ($P < 0.001$). In contrast, adolescents in the group with MVPA of < 30 min/day and BRI quartiles of Q4 (OR = 1.62, 95% CI: 1.30 ~ 2.02) had a higher risk of developing psychological symptoms ($P < 0.001$). Additionally, the risk of psychological symptoms was also higher in adolescents in the MVPA 30–60 min/day and BRI Q4 group (OR = 1.34, 95% CI: 1.06–1.69), and in the MVPA < 30 min/day and BRI Q3 group (OR = 1.34, 95% CI: 1.07–1.67) ($P < 0.05$). The same trend was observed in boys and girls.

Figure 4 shows the trend of ORs for ordered logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents. Overall, as the duration of MVPA decreased and BRI increased, adolescents had an increased risk of developing psychological symptoms, i.e., the OR value increased and shifted more to the right.

The result of likelihood ratio test showed that the interactions between physical activity and body roundness index was not significant($P = 0.50$). Figures 5 and 6 shows the dose-response relationship curve between BRI, MVPA and psychological symptoms in Chinese adolescents. As can be seen from the figure, Chinese adolescents obtained the lowest risk of psychological symptoms with an BRI of 2 and MVPA of about 30 min/day.

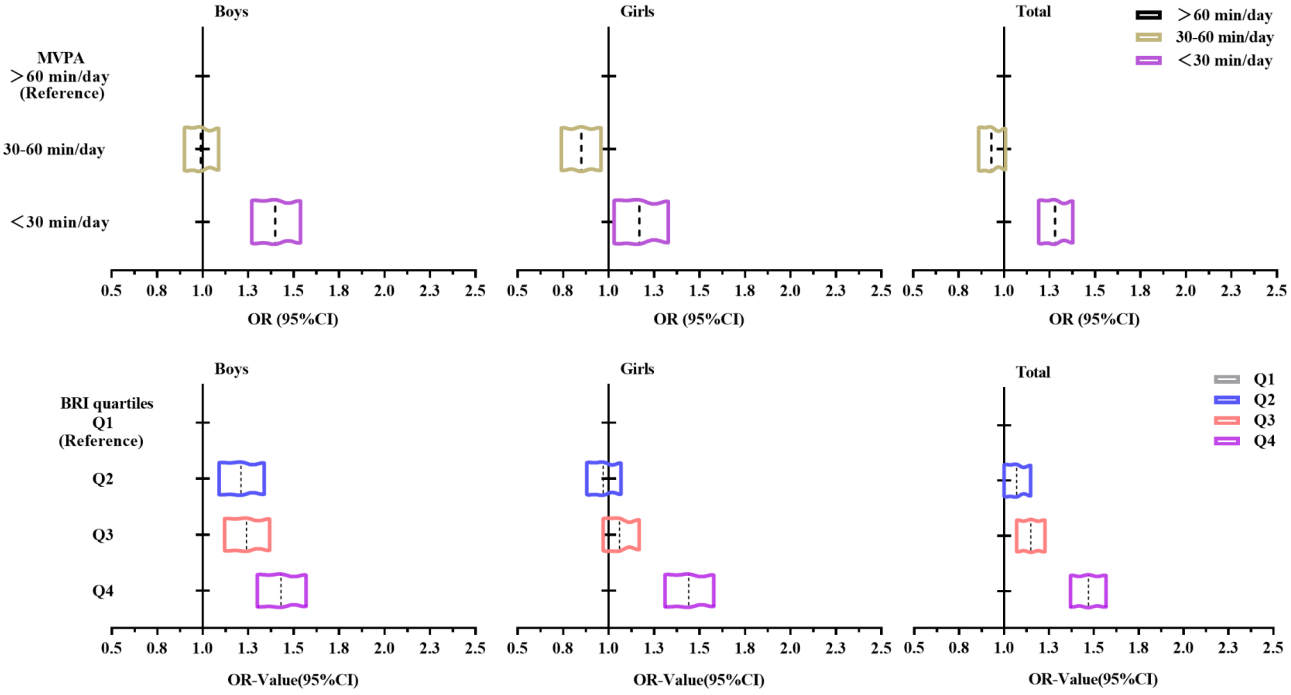

Fig. 3 Trends in ORs of logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents

Discussion

The prevalence of psychological symptoms among adolescents continues to rise, posing a serious threat to health in adolescence and future adulthood [37]. Therefore, investigating and analyzing its related influencing factors can have a positive effect on reducing the prevalence of adolescent psychological symptoms. The results of this study showed that the prevalence of adolescent psychological symptoms in mainland China was 20.3%. This result is high compared with the results of related studies (8.1%) [38], however, it is also more consistent with the results of studies comparing (21.37%) [26]. The reason for this is that there are certain differences related to the criteria for defining psychological symptoms, the area of investigation, and the age distribution in different studies, and thus accurate cross-sectional comparisons cannot be made. In conclusion, there are two tiers of mainland Chinese adolescents with psychological symptoms and problems, which deserve attention and focus. The results of this study also showed that the proportion of the number of mainland Chinese adolescents with MVPA durations of < 30 min/day, 30–60 min/day, and > 60 min/day were 46.0%, 40.0%, and 14.0%, respectively. It can be seen that there is still a big gap between the MVPA of adolescents in mainland China to reach the standard of participating in exercise for not less than 60 min/day as recommended by the physical activity guidelines. Research has found that insufficient physical activity among adolescents will have a series of negative impacts on their physical and mental development and that physical activity levels among adolescents should be effectively increased to promote healthy physical and mental development [39, 40]. The results of this study also showed that Chinese adolescents had a BRI value of (2.02 ± 0.95), which was higher for boys than for girls, in line with the findings of related studies [41]. BRI, as an important indicator of body fatness, has a high sensitivity for evaluating health problems [42]. The higher BRI for boys than for girls is related to the fact that girls are more conscious of their external physical beauty and pay particular attention to dietary control and exercise in their lives. It may also be related to the fact that girls are born with lower waist circumference than boys due to congenital sex factors [43].

Regarding the association between MVPA and psychological symptoms, the prevalence of psychological symptoms was lower in adolescents with longer MVPA in mainland China, which is consistent with the findings of related studies [44]. The study found that adolescents who spent more time in MVPA activities had a better mental state, while more time was spent in offline exercise time, which has a positive effect on and helps the development of adolescent mental health through communication and exchange with peers [45]. It has also been found that increased MVPA promotes the body's dopamine secretion, which has a positive effect on people's mental health promotion [46]. The present study also showed a positive correlation between BRI and the prevalence of psychological symptoms in adolescents, i.e., the higher the BRI, the higher the prevalence of psychological symptoms.

Table 5 Ordered logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents

Sex	Classification		Psychological symptoms	
	MVPA	BRI quartiles	OR (95% CI)	*P*-value
Boys	>60 min/day	Q1	1.00	
		Q2	0.95(0.79 ~ 1.15)	0.595
		Q3	1.01(0.84 ~ 1.22)	0.921
		Q4	1.21(1.01 ~ 1.45)	0.044
	30–60 min/day	Q1	0.92(0.79 ~ 1.07)	0.286
		Q2	0.88(0.75 ~ 1.02)	0.090
		Q3	0.98(0.84 ~ 1.14)	0.756
		Q4	1.35(1.17 ~ 1.56)	<0.001
	<30 min/day	Q1	1.27(1.10 ~ 1.47)	0.001
		Q2	1.47(1.27 ~ 1.70)	<0.001
		Q3	1.53(1.33 ~ 1.77)	<0.001
		Q4	1.87(1.62 ~ 2.15)	<0.001
Girls	>60 min/day	Q1	1.00	
		Q2	0.97(0.77 ~ 1.24)	0.822
		Q3	1.08(0.86 ~ 1.37)	0.511
		Q4	1.32(1.06 ~ 1.65)	0.014
	30–60 min/day	Q1	0.94(0.77 ~ 1.15)	0.579
		Q2	1.11(0.91 ~ 1.36)	0.293
		Q3	1.20(0.99 ~ 1.46)	0.068
		Q4	1.35(1.12 ~ 1.63)	0.002
	<30 min/day	Q1	1.42(1.16 ~ 1.73)	0.001
		Q2	1.76(1.45 ~ 2.13)	<0.001
		Q3	1.70(1.40 ~ 2.06)	<0.001
		Q4	2.06(1.71 ~ 2.48)	<0.001
Total	>60 min/day	Q1	1.00	
		Q2	0.92(0.68 ~ 1.24)	0.572
		Q3	0.90(0.66 ~ 1.23)	0.514
		Q4	1.01(0.73 ~ 1.40)	0.942
	30–60 min/day	Q1	0.86(0.68 ~ 1.08)	0.198
		Q2	0.65(0.51 ~ 0.82)	<0.001
		Q3	0.73(0.57 ~ 0.93)	0.010
		Q4	1.34(1.06 ~ 1.69)	0.014
	<30 min/day	Q1	1.11(0.89 ~ 1.38)	0.359
		Q2	1.22(0.98 ~ 1.52)	0.077
		Q3	1.34(1.07 ~ 1.67)	0.010
		Q4	1.62(1.30 ~ 2.02)	<0.001

Note: MVPA, moderate-to-vigorous physical activity; BRI, body roundness index; OR, Odds Ratio; 95% CI, 95% Confidence Interval. In ordered logistic regression analysis, the model adjusted for age, family economic income, sleep duration, snack consumption, standing long jump, and 50-meter run

This study shows that BRI, as an important indicator of obesity, has a positive effect on the evaluation of the occurrence of various chronic diseases in human beings [47]. The higher the BRI in this study, the more often the body weight is in an overweight or even obese state, this type of adolescent tends to have a lower level of physical activity, static behavior time, video screen behavior time is relatively long, less offline social time is bound to have a certain negative impact on mental health. It was found that the prevalence of psychological symptoms in obese people was significantly higher compared to normal people, which is consistent with the findings of this study [48, 49].

The results of the present study also showed that the prevalence of psychological symptoms was significantly higher in adolescents with lower MVPA and higher BRI in the ordered regression analysis of MVPA and BRI with psychological symptoms. Of interest, in this study, adolescents with MVPA of 30–60 min/day and BRI quartiles Q2 group were at lower risk for prevalence of psychological symptoms. This suggests that higher MVPA is not better and lower BRI is not better. Maintaining reasonable levels of MVPA and BRI positively impacts mental health. Past studies have found that too high a level of MVPA can lead to physical fatigue, resulting in a low body immunity and can also affect mental health [50].

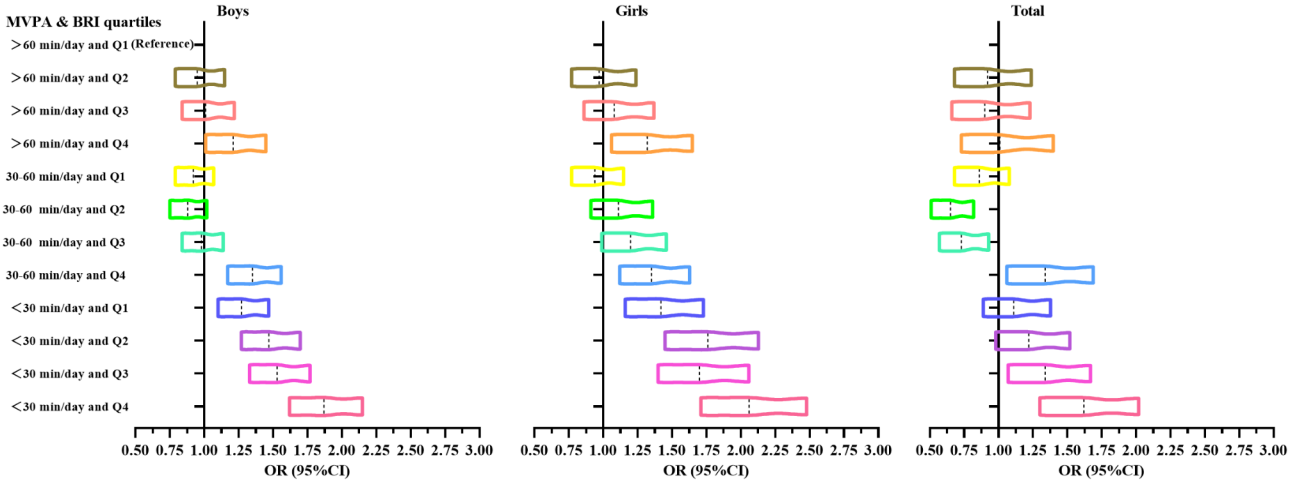

Fig. 4 Trends in ORs of ordered logistic regression analysis of MVPA and BRI with psychological symptoms in Chinese adolescents

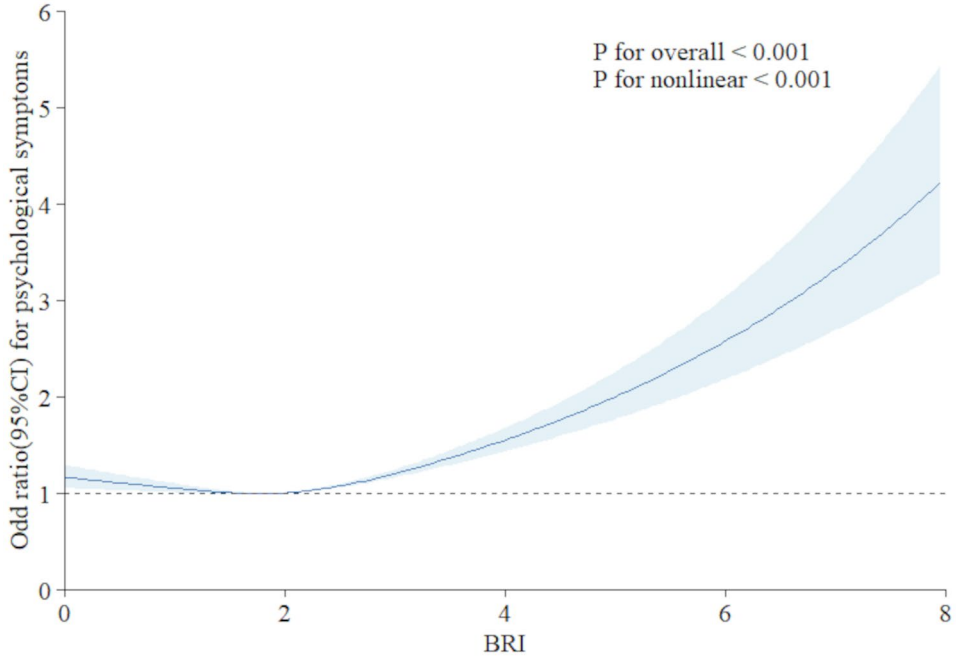

Fig. 5 Dose-response relationship curve between BRI and psychological symptoms in Chinese adolescents
Note: Data were fitted by a logistic restricted cubic spline regression model adjusted for age, family economic income, sleep duration, snack consumption, standing long jump, and 50-meter run with 3 knots at the 10th, 50th, 90th percentiles of BRI (reference is the median). OR, odds ratio; CI, confidence interval; BRI, body roundness index

It has also been shown that a low BRI means that the body is at a wasting level, which can lead to a weakened immune system and various illnesses, which can have a negative impact on the development of mental health [51]. This suggests that MVPA and BRI have a combined additive effect on the occurrence of psychological symptoms. In the future, we should pay special attention to controlling the levels of MVPA and BRI to keep them within a reasonable range, to better promote the physical and mental health development of adolescents in mainland China.

The present study has certain strengths and limitations. Strengths: First, to the best of our knowledge, this study is the first to analyze the association relationship between MVPA and BRI with psychological symptoms in adolescents in mainland China. This study can provide a reference for the prevention and intervention of adolescents' psychological symptoms in mainland China. Second, the participants of this study were selected from five different regions in mainland China, which is a large and representative sample size. However, this study also has certain limitations. First, this study was a cross-sectional study,

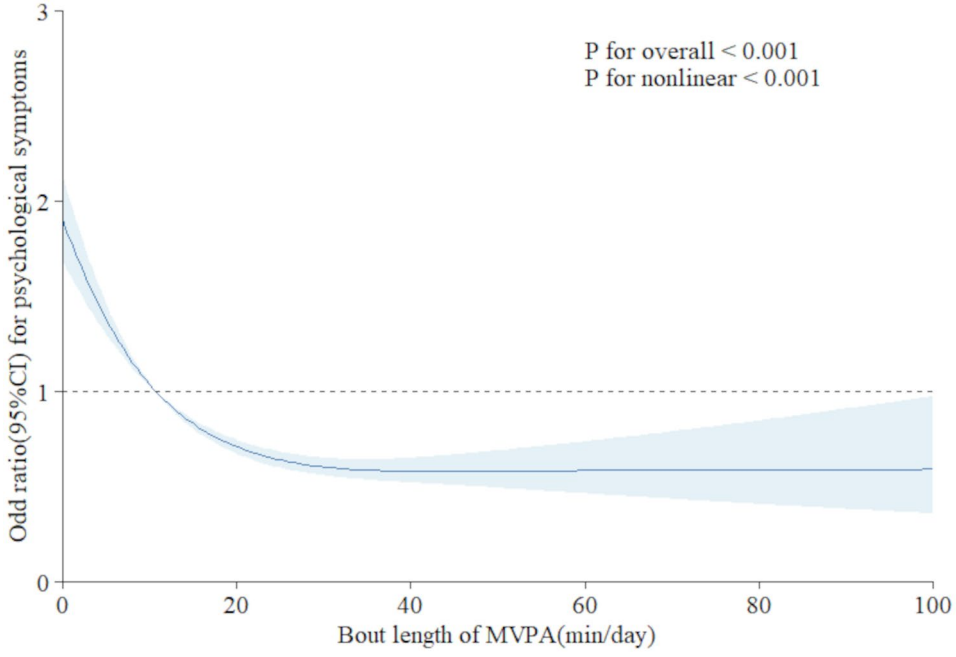

Fig. 6 Dose-response relationship curve between MVPA and psychological symptoms in Chinese adolescents
Note: Data were fitted by a logistic restricted cubic spline regression model adjusted for age, family economic income, sleep duration, snack consumption, standing long jump, and 50-meter run with 3 knots at the 10th, 50th, 90th percentiles of MVPA (reference is the median). OR, odds ratio; CI, confidence interval; MVPA, moderate-to-vigorous physical activity

which could only analyze the cross-sectional associations that existed between MVPA and BRI and psychological symptoms and could not understand the causal associations that existed between them. Second, the covariates included in this study were limited. In the future, factors such as whether or not they smoke, home parents' exercise habits, and education should be included to better analyze the results. Thirdly, MVPA in this study was assessed using questionnaires, and there are some differences between them and the real situation, which inevitably have some impact on the analyzed results. In the future, accelerometers and other tools should be used to assess the physical activity of participants to analyze the results more accurately. Fourth, as the study investigaged psychological symptoms in school-aged children, it is a limitation when not accounting for other factors related to stress/anxienty/depression in this age group, such as academic stress, social difficulties like problems with classmates or friends, peer pressures, adapting to new environment (changing school, changing class, moving home), puberty-related body changes, or family problem (parental divorce or seperation). These factors should be included in future analyses. Finally, whether there is a dose-response relationship between BRI and psychological symptoms is also a limitation of this study, which should be remedied in future studies.

Conclusions

There is an association between MVPA and BRI and psychological symptoms in adolescents in mainland China. Decreasing MVPA and increasing BRI in adolescents are associated with the increasing prevalence of psychological symptoms in adolescents. In the future, MVPA levels in adolescents in mainland China should be effectively increased to maintain them at 30–60 min per day. At the same time, the continuous elevation of BRI should be controlled to keep it within a reasonable range to prevent the prevalence of psychological symptoms and better promote the development of adolescent mental health.

Acknowledgements
To protect the privacy of participants, the questionnaire data will not be disclosed to the public. If necessary, you can contact the corresponding author.

Author contributions
Conceptualization, Feng Zhang, Cunjian Bi, Yuqiang Li; Data curation, Feng Zhang, Xiaojian Yin; Formal analysis, Cunjian Bi; Funding acquisition, Feng Zhang, Cunjian Bi; Investigation, Cunjian Bi; Methodology, Cunjian Bi; Project administration, Feng Zhang; Resources, Jun Li; Software, Feng Zhang; Supervision, Feng Zhang; Validation, Yun Liu; Visualization, Xiaokang Ran; Writing—original draft, Feng Zhang, Cunjian Bi, Yuqiang Li; Writing—review & editing, Feng Zhang, Cunjian Bi, Yuqiang Li, Xiaojian Yin; All authors have read and agreed to the published version of the manuscript.

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Data availability
To protect the privacy of participants, the questionnaire data will not be disclosed to the public. If necessary, you can contact the corresponding author.

Declarations

Human ethics and consent to participate
This study was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from parents or guardians prior to the assessment of participants in this study, and participants volunteered to be assessed for this study. This study was approved by the Human Ethics Committee of Ikebukuro College (2023874592).

Informed consent
Informed consent was obtained from all subjects involved in the study.

Clinical trial number
Not applicable.

Conflicts of interest
The authors declare no conflict of interest.

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