International Journal of
Mental Health Promotion

Tech Science Press

http://doi.org/10.32604/ijmhp.2026.079935

ARTICLE

Association between Physical Activity Intensity and Depressive Symptoms in College Students: A 3-Year Prospective Cohort Study

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Received: 31 January 2026; Accepted: 09 May 2026; Published: 30 July 2026

ABSTRACT: Background: Literature suggests that physical activity has a preventive effect on depressive symptoms, yet the association between the intensity of physical activity (a core element of physical activity) and depressive symptoms remains unclear. This study explores this association between physical activity intensity and depressive symptoms in college students. **Methods:** Using a cohort study design, a 3-year follow-up survey was conducted from 2017–2020 among 1415 college students (1108 females, 78.3%; 307 males, 21.7%) from Shenyang Normal University from 2017 to 2020. The International Physical Activity Questionnaire-Short Form (IPAQ-SF) and Zung Self-Rating Depression Scale (SDS) were used to evaluate the physical activity intensity and depressive symptoms of these students. Logistic regression was then used to analyze the association between physical activity intensity and depressive symptoms. **Results:** The analysis showed that, compared with participants with lower levels of low-intensity physical activity, those with higher levels had a 61.7% (OR = 0.38, 95% CI: 0.28–0.52, $p < 0.001$) lower incidence of depressive symptoms in full-adjusted model. Similarly, moderate-intensity physical activity also appeared to reduce the incidence of depressive symptoms by approximately 20% (OR = 0.80, 95% CI: 0.59–1.08, $p = 0.14$) in the full-adjusted model. Conversely, increased vigorous-intensity physical activity was associated with a 50.4% (OR = 1.50, 95% CI: 1.12–2.02, $p = 0.007$) higher risk of depressive symptoms. **Conclusions:** Physical activity intensity is closely related to depressive symptoms, and higher levels of low- to moderate-intensity physical activity are associated with a lower incidence of depressive symptoms. This study controls for baseline depressive symptoms status and multiple confounding factors, and is the first to clarify the potential positive association between vigorous-intensity physical activity and depressive symptoms in Chinese college students. Further research is needed to reveal the causal relationship and the internal mechanism.

KEYWORDS: Physical activity; exercise intensity; depressive symptoms; cohort study; school health

1 Introduction

College marks a stage, where individuals experience a rapid growth of physical and psychological health and face the progressive transition from student life to the professional world. However, due to identity issues with academic, social, and personal-emotional functioning at university, college students become a high-risk group for mental issues [1]. As such, the prevalence of depressive symptoms exhibits an upward trend during college. A study encompassing 64 reports showed that the global prevalence of depressive symptoms among college students has reached 33.6% [2]. In China, the prevalence of depressive symptoms among college students is 27.72%, but data vary among different areas [3]. Depressive symptoms not only affect college students' academic performance [4] but can also exert negative effects on their quality of life [5].

As an adjustable lifestyle, physical activity has received extensive attention for its potential role in mental health. Recently, an increasing amount of evidence has suggested that appropriate physical activity helps reduce the risk of developing depressive symptoms. For instance, cross-sectional studies observed that active physical exercise is negatively correlated with the risk of developing depressive symptoms [6,7]. Similarly, cohort studies showed that a greater amount of physical activity plays a protective role against depressive symptoms [7–9]. Overall, the association between total physical activity and the risk of depressive symptoms appears to be generally linear. However, this relationship may differ between physical activity intensity and depressive symptoms. For instance, Dinger et al. conducted a survey among 67861 college students, demonstrating that college students with a greater amount of moderate- to vigorous-physical activity have a lower rate of depressive symptoms; additionally, there may be a dose-response relationship between moderate- to vigorous-physical activity and depressive symptoms [10]. However, scholars have also found a significant negative correlation between low-intensity physical activity and depressive symptoms [11,12]. This inconsistency may stem from differences in research design and sample characteristics. In addition, some studies identified an inverted U-shaped relationship between exercise intensity and mental health [13,14]. This relationship posits that moderate-intensity physical activity can maximize mental health benefits, as it induces optimal neurobiological and psychological responses (e.g., endorphin release, improved neurotransmitter balance, enhanced self-efficacy), whereas low-intensity activity may provide insufficient physiological and psychological stimulation, and vigorous-intensity activity may induce excessive fatigue and stress responses. Therefore, the current evidence has not reached a consensus on whether physical activity of different intensities differ in their effectiveness in alleviating depressive symptoms. Further discussions of the association between physical activity of different intensities and depressive symptoms among college students would thus provide more precise scientific evidence for developing mental health intervention strategies.

This study explores whether physical activity intensity is correlated with the risk of depressive symptoms and also verifies the potential differences in the association between different physical activity intensities and the risk of depressive symptoms among college students in China, thereby providing empirical support for developing mental health intervention measures in higher educational institutions.

2 Participants and Methodology

2.1 Participants

This study is a part of the Fitness Improvement Tactics in Youth Project, conducted at Shenyang Normal University in Liaoning Province, starting from November 2017. Baseline data were collected from students who enrolled during the same year, after which the cohort was followed up annually until graduation, resulting in a total follow-up period of three years. The research protocol was approved by the Institutional Review Board of Zhejiang University (No. 2021[004]), as it is part of a larger project led by Zhejiang University. At baseline, a total of 4717 college students enrolled in 2017 were invited to participate in the study. After the initial recruitment, participants were excluded if information on physical examination, depressive symptoms, or physical activity was unavailable. We further removed individuals with missing baseline covariates, including demographic characteristics, lifestyle factors, and physical fitness variables. Additionally, 845 participants with missing follow-up data on depressive symptoms between 2018 and 2020 were excluded. As the exclusion criteria were applied sequentially, the participants who met multiple exclusion conditions were categorized according to the first applicable criterion to avoid double-counting. Ultimately, data from a total of 1415 participants were included in the cohort study and analyzed, as illustrated in Fig. 1.

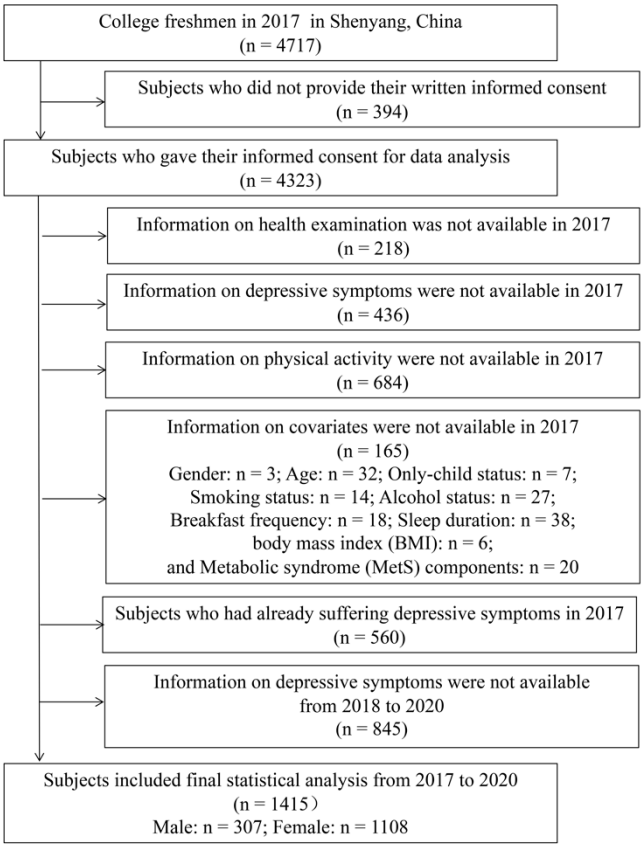

Figure 1: Schematic presentation of the flow of participants through screening.

2.2 Methodology

2.2.1 Depressive Symptoms

We used the Zung Self-Rating Depression Scale (SDS) [15] to measure participants' depressive symptoms. The reliability and validity of the scale are well established [16], and it has been widely employed in depression research. In this study, the reliability and validity of the scale were 0.843 and 0.897, respectively. The scale consists of 20 items related to characteristic symptoms of depression, with each item scored on a scale from 1 to 4. Following the Chinese version of SDS [17], item scores were summed and multiplied by 1.25 to generate a standardized score ranging from 25 to 100. Participants with a standardized score $\geq$ 53 were defined as having depressive symptoms.

2.2.2 Physical Activity Intensity

We also employed the International Physical Activity Questionnaire Short-Form (IPAQ-SF) [18] to assess participants' physical activity intensity. The scale exhibits relatively high reliability and validity among college students [18,19]. It consists of seven items, requiring participants to recall and report the frequency and duration of walking, moderate activities, vigorous activities, and sedentary behavior over the past week. According to the IPAQ scoring protocol, Metabolic Equivalent of Task (MET) values were assigned to each activity intensity as follows [18]: low intensity (walking) = 3.3 METs, moderate intensity = 4.0 METs, and vigorous intensity = 8.0 METs. The total amount of physical activity for each intensity level was calculated

in MET·hours per week (MET·h/week). Physical activity intensity was divided into tertiles based on its distribution in the statistical analysis.

2.2.3 Covariates

To minimize the influence of other factors on the relationship between physical activity intensity and depressive symptoms, covariates were added to all analytical models [11]. In terms of confounders, 5 models were designed: Model 1 included gender, age, ethnicity, only-child status, and body mass index. Model 2 included Model 1 and lifestyle variables such as smoking status, alcohol use, breakfast consumption, and sleep duration. Model 3 included Model 2 and physical fitness variables such as body mass index, grip strength, and number of metabolic syndrome components. Model 4 included Model 3 and standard depressive symptoms score at baseline. Model 5 included Model 4 and other two physical activity intensity levels.

2.2.4 Statistical Methods

Data analysis and processing were performed using SPSS 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as means with standard deviations, while categorical variables were expressed as number with percentages. Basic participant characteristics were compared across physical activity groups using one-way analysis of variance (ANOVA) for continuous variables and the Chi-square test for categorical variables. Binary logistic regression analysis was employed to examine the association between physical activity intensity and the risk of developing depressive symptoms, with findings reported as odds ratios (OR) with 95% confidence intervals (95% CI).

3 Results

3.1 Basic Information of Participants

Participants were classified into groups according to their physical activity intensity levels. Among the 1415 participants, 307 were male, accounting for 21.7%, and 1108 were female, representing 78.3%. No inter-group differences were observed in covariates, including gender, age, ethnicity, only-child status, body mass index, smoking status, alcohol use, sleep duration, grip strength, and metabolic syndrome. Nevertheless, significant differences between groups were identified with respect to breakfast consumption (Table 1).

Table 1: Participants' characteristics according to physical activity levels in 2017 among college students (n = 1415).

Variable[a]	Tertiles of Total Physical Activity Levels in 2017			
	T1	T2	T3	*p*-Value[b]
METs·(hours/week), range	≤36.4	36.4–89.3	>89.3	/
Participants, n (%)	484 (34.2)	462 (32.7)	469 (33.1)	/
Sex (female), n (%)	379 (78.3)	361 (78.1)	368 (78.5)	0.993
Age (years), mean ± SD	18.1 ± 0.80	18.1 ± 0.72	18.1 ± 0.81	0.967
Han ethnicity, n (%)	412 (85.1)	390 (84.4)	386 (82.3)	0.470
Only child (yes), n (%)	280 (57.9)	269 (58.2)	262 (55.9)	0.734
BMI (kg/m^2), mean ± SD	21.9 ± 4.1	21.8 ± 4.0	21.6 ± 3.7	0.392
Smoking status, n (%)				0.478
Never	471 (97.3)	446 (96.5)	451 (96.2)	
Former	6 (1.2)	11 (2.4)	8 (1.7)	
Current	7 (1.4)	5 (1.1)	10 (2.1)	
Alcohol use (yes), n (%)	49 (10.1)	46 (10.0)	46 (10.0)	0.200

Table 1: *Cont.*

Variable[a]	Tertiles of Total Physical Activity Levels in 2017			
	T1	T2	T3	*p*-Value[b]
Breakfast (times/week), n (%)				0.047
<4	89 (18.4)	73 (15.8)	57 (12.2)	
4–5	81 (16.7)	65 (14.1)	69 (14.7)	
6–7	314 (64.9)	324 (70.1)	343 (73.1)	
Sleep duration (hours/day), n (%)				0.800
<6	121 (25.0)	119 (25.8)	102 (21.7)	
6–7	192 (39.7)	175 (37.9)	189 (40.3)	
7–8	129 (26.7)	129 (27.9)	131 (27.9)	
≥8	42 (8.7)	39 (8.4)	47 (10.0)	
Grip strength (kg), mean ± SD	26.5 ± 7.5	26.9 ± 8.2	27.0 ± 8.0	0.667
MetS components, mean ± SD	1.2 ± 0.5	1.2 ± 0.5	1.2 ± 0.4	0.716

Note: [a]Categorized variables were presented as numbers and percentages, and continuous variables were presented as means and standard deviations; [b]Analysis of variance or χ^2 test, as appropriate. Abbreviations: METs, metabolic equivalents of task; BMI, body mass index; MetS, metabolic syndrome.

3.2 Physical Activity Intensity and Depressive Symptoms

The protective effect of low-intensity physical activity was stable, the effect of moderate-intensity physical activity was weaker, and vigorous-intensity physical activity showed a risk effect.

As per Table 2, the correlation between physical activity and depressive symptoms varies across intensity levels. The unadjusted model and Models 1–5 demonstrated that, as the total amount of low-intensity physical activity increased, the risk of developing depressive symptoms decreased significantly. Specifically, in Model 5, in terms of low-intensity physical activity, the incidences of depressive symptoms among participants with higher amounts of physical activity was reduced by 50.4% (T2, OR = 0.50, 95% CI: 0.37–0.66) and 61.7% (T3, OR = 0.38, 95% CI: 0.28–0.52), respectively, compared to those with lower amounts of physical activity. In terms of moderate-intensity physical activity, when the baseline depression status and the other two intensity levels of physical activity were not considered (i.e., in Model 3), compared to participants with low weekly amounts of physical activity, those with high weekly amounts of physical activity exhibited a lower incidence of depressive symptoms, that is, by 26.2% (T2, OR = 0.74, 95% CI: 0.57–0.96) and 31.7% (T3, OR = 0.68, 95% CI: 0.52–0.90), respectively. However, after controlling for another three variables, the *p*-value increased to 0.097. By contrast, a statistically significant positive association between vigorous-intensity physical activity and depressive symptoms was observed after adjusting for all covariates (T3, OR = 1.50, 95% CI: 1.12–2.02).

Table 2: Association between physical activity intensity in 2017 and depressive symptoms from 2018 to 2020 among college students (n = 1415).

Physical Activity Intensity	Tertiles of Physical Activity at Different Intensity Levels in 2017			
Low Intensity	**T1, n = 473**	**T2, n = 482**	**T3, n = 460**	***p*-Value**
METs·(hours/week), range	≤13.2	13.2–42.35	>42.35	/
Depressive symptoms, n	346	270	236	/
Non-adjusted model, OR (95%CI)	1.00 (ref)	0.47 (0.36, 0.61)	0.39 (0.29, 0.51)	<0.001
Adjusted Model 1, OR (95%CI)	1.00 (ref)	0.47 (0.36, 0.62)	0.39 (0.30, 0.52)	<0.001
Adjusted Model 2, OR (95%CI)	1.00 (ref)	0.48 (0.37, 0.64)	0.40 (0.30, 0.53)	<0.001
Adjusted Model 3, OR (95%CI)	1.00 (ref)	0.48 (0.37, 0.63)	0.40 (0.30, 0.53)	<0.001
Adjusted Model 4, OR (95%CI)	1.00 (ref)	0.48 (0.38, 0.66)	0.39 (0.29, 0.52)	<0.001
Adjusted Model 5, OR (95%CI)	1.00 (ref)	0.50 (0.37, 0.66)	0.38 (0.28, 0.52)	<0.001

Table 2: *Cont.*

Physical Activity Intensity	Tertiles of Physical Activity at Different Intensity Levels in 2017			
Moderate Intensity	**T1, n = 479**	**T2, n = 520**	**T3, n = 416**	***p*-Value**
METs·(hours/week), range	≤4	4–20	>20	/
Depressive symptoms, n	315	304	233	/
Non-adjusted model, OR (95%CI)	1.00 (ref)	0.73 (0.57, 0.95)	0.66 (0.51, 0.87)	0.007
Adjusted Model 1, OR (95%CI)	1.00 (ref)	0.74 (0.56, 0.94)	0.66 (0.50, 0.87)	0.006
Adjusted Model 2, OR (95%CI)	1.00 (ref)	0.74 (0.57, 0.96)	0.68 (0.52, 0.90)	0.015
Adjusted Model 3, OR (95%CI)	1.00 (ref)	0.74 (0.57, 0.96)	0.68 (0.52, 0.90)	0.014
Adjusted Model 4, OR (95%CI)	1.00 (ref)	0.74 (0.56, 0.96)	0.71 (0.53, 0.94)	0.064
Adjusted Model 5, OR (95%CI)	1.00 (ref)	0.75 (0.57, 0.98)	0.80 (0.59, 1.08)	0.097
Vigorous Intensity	**T1, n = 515**	**T2, n = 474**	**T3, n = 426**	***p*-Value**
METs·(hours/week), range	≤4	4–24	>24	/
Depressive symptoms, no.	293	287	272	/
Non-adjusted model, OR (95%CI)	1.00 (ref)	1.16 (0.90, 1.50)	1.34 (1.03, 1.74)	0.094
Adjusted Model 1, OR (95%CI)	1.00 (ref)	1.14 (0.88, 1.47)	1.30 (0.99, 1.69)	0.159
Adjusted Model 2, OR (95%CI)	1.00 (ref)	1.12 (0.89, 1.50)	1.31 (1.00, 1.72)	0.138
Adjusted Model 3, OR (95%CI)	1.00 (ref)	1.15 (0.89, 1.49)	1.31 (1.00, 1.71)	0.152
Adjusted Model 4, OR (95%CI)	1.00 (ref)	1.11 (0.86, 1.45)	1.32 (1.00, 1.74)	0.022
Adjusted Model 5, OR (95%CI)	1.00 (ref)	1.12 (0.86, 1.46)	1.50 (1.12, 2.02)	0.023

Abbreviation: METs, metabolic equivalents of task.

Low- and moderate-intensity, as well as moderate- and vigorous-intensity physical activity, were combined for further analyses. As shown in Table 3, a significant association with depressive symptoms was observed only for low-to-moderate-intensity physical activity. After adjusting for all covariates (Model 5), compared with college students who engaged in a lower total amount of low-to-moderate-intensity physical activity per week, those with a higher total amount exhibited a 57.3% (T3, OR = 0.43, 95% CI: 0.32–0.57) lower risk of depressive symptoms. Contrastingly, no significant association was observed between moderate-to-vigorous-intensity physical activity and depressive symptoms.

Table 3: Association between combined physical activity intensity in 2017 and depressive symptoms from 2018 to 2020 among college students (n = 1415).

Physical Activity Intensity	Tertiles of Physical Activity at Different Intensity Levels in 2017			
LMPA	**T1, n = 470**	**T2, n = 477**	**T3, n = 468**	***p*-Value**
METs·(hours/week), range	≤23.8	23.8–60.8	>60.8	/
Depressive symptoms, n	333	278	241	/
Non-adjusted model, OR (95%CI)	1.00 (ref)	0.58 (0.44, 0.75)	0.44 (0.33, 0.57)	<0.001
Adjusted Model 1, OR (95%CI)	1.00 (ref)	0.57 (0.43, 0.75)	0.44 (0.34, 0.58)	<0.001
Adjusted Model 2, OR (95%CI)	1.00 (ref)	0.58 (0.44, 0.76)	0.45 (0.35, 0.60)	<0.001
Adjusted Model 3, OR (95%CI)	1.00 (ref)	0.58 (0.44, 0.76)	0.45 (0.34, 0.59)	<0.001
Adjusted Model 4, OR (95%CI)	1.00 (ref)	0.57 (0.44, 0.75)	0.44 (0.33, 0.58)	<0.001
Adjusted Model 5, OR (95%CI)	1.00 (ref)	0.58 (0.44, 0.77)	0.43 (0.32, 0.57)	<0.001
MVPA	**T1, n = 484**	**T2, n = 459**	**T3, n = 472**	***p*-Value**
METs·(hours/week), range	≤12	12–46	>46	/
Depressive symptoms, n	306	272	274	/
Non-adjusted model, OR (95%CI)	1.00 (ref)	0.85 (0.85, 1.00)	0.81 (0.62, 1.04)	0.232
Adjusted Model 1, OR (95%CI)	1.00 (ref)	0.83 (0.64, 1.08)	0.79 (0.60, 1.02)	0.168
Adjusted Model 2, OR (95%CI)	1.00 (ref)	0.85 (0.65, 1.11)	0.79 (0.61, 1.04)	0.217
Adjusted Model 3, OR (95%CI)	1.00 (ref)	0.84 (0.65, 1.10)	0.79 (0.60, 1.03)	0.197
Adjusted Model 4, OR (95%CI)	1.00 (ref)	0.86 (0.66, 1.12)	0.89 (0.67, 1.17)	0.500
Adjusted Model 5, OR (95%CI)	1.00 (ref)	0.84 (0.64, 1.10)	0.92 (0.70, 1.22)	0.440

Abbreviation: METs, metabolic equivalents of task; LMPA, low- to moderate-intensity physical activity; MVPA, moderate- to vigorous-intensity physical activity.

The multicollinearity analyses showed that all variance inflation factors (VIF) values ranged from 1.014 to 2.665, and all tolerance values were greater than 0.1, indicating no evidence of significant multicollinearity.

4 Discussion

This cohort study examined the association between physical activity intensity and depressive symptoms among college students. After a three-year follow-up, low-intensity physical activity was found to be closely associated with a lower incidence of depressive symptoms. This association remained statistically significant after adjusting for covariates. High participation in low-intensity physical activity led to a 61.7% reduction in the risk of developing depressive symptoms. Moreover, participation in moderate-intensity physical activity lowered the risk of depressive symptoms.

These findings are consistent with the results of several extant studies. A recent meta-analysis found that pooled random-effects models resulted in an odd ratio of 0.90 for the highest-intensity versus the lowest-intensity physical activity group in adults and older adults, but 0.94 for the moderate- to vigorous-physical activity group [20]. A two-year cohort study targeting older adults examined the association between low-intensity physical activity and the prevalence of depressive symptoms after adjusting for moderate-to-vigorous-intensity physical activity and other covariates. The results indicated low-intensity physical activity to be associated with a reduced risk of subsequent depressive symptoms in later life. By contrast, when the same analytical model was applied to moderate-to-vigorous-intensity physical activity, no comparable association was observed [21]. Moreover, a meta-analysis of physical activity interventions in depressive symptoms showed that seven out of 21 studies employed low- to moderate-intensity physical activity, while the other ten adopted vigorous-intensity physical activity interventions. The results indicated that the effectiveness (Hedges g = −0.41) of low- to moderate-intensity physical activity interventions was significantly superior to the effectiveness (Hedges g = −0.13) of vigorous-intensity physical activity interventions [22]. In addition, animal research has shown that regular low-intensity physical activity could improve depressive status by promoting the increase in neuronal cell proliferation and angiogenesis in mice [23]. However, some studies have also shown different results from ours. A two-year prospective cohort study of Chinese middle and high school students showed that individuals in the high level of moderate- to vigorous-intensity physical activity group had a lower risk of developing new-onset depressive symptoms, compared to those who did not engage in any moderate- to vigorous-physical activity [7]. Another pooled analysis of six waves cohort studies indicated that moderate and vigorous intensity physical activity were associated with a reduced risk of depressive symptoms in US adults, but not in low-intensity physical activity was not [24]. The different results may be explained by the higher proportion of male participants and the age differences in these studies.

The association between low-intensity physical activity and a low risk of depressive symptoms may be explained as follows. First, low-intensity physical activity is typically relaxing and pleasant without causing excessive fatigue and stress. Specifically, when performing low-intensity physical activity, individuals are likely to feel relaxed and comfortable and achieve a positive psychological status that is helpful in reducing anxiety and depression [25]. In addition, low-intensity physical activity can elicit moderate physiological stimulation, such as enhancing blood circulation and increasing the heart rate, without excessively activating the body's stress response. This level of physiological stimulation may promote the release of neurotransmitters involved in emotional regulation, such as the production of dopamine and endorphins, thereby improving mood and helping prevent depressive symptoms [26]. However, the physiological effects induced by a single bout of exercise cannot be sustained for an extended period, as many acute responses typically diminish within several hours after exercise or gradually subside within

two to three days [27]. Therefore, physical activity with higher frequency and longer duration may elicit more favorable stimulatory effects on the body. We also found that the protective effect of combined low- to moderate-intensity physical activity to be better than that of single low-intensity activity. This result may be partially attributable to the total volume of physical activity and to activity diversity. Firstly, students engaging in combined low and moderate-intensity activities are likely to accumulate a greater overall amount of energy expenditure, which has been consistently associated with improvements in depressive symptoms [28]. Second, engaging in a combination of activity intensities may provide more varied physiological and psychological stimulation, and this pattern may help prevent monotony and increase adherence [29,30]. Additionally, we further found that the frequency of participation and the duration of individual sessions are greater for low-intensity physical activity compared to vigorous-intensity activity. Specifically, the participants in the low-intensity group engaged in 5.7 sessions of physical activity, adding up to approximately 133 min of physical activity per week, and those in the moderate-intensity group engaged in 4.1 sessions and 107 min per week, whereas the participants in the vigorous-intensity group engaged in 3.4 sessions of physical activity, with a total of approximately 98 min of physical activity per week. Therefore, given the effects of higher frequency and longer duration, low-intensity physical activity may play a more effective role in preventing depressive symptoms. Additionally, compared to moderate- to vigorous-intensity physical activity, low-intensity activity is usually easier to initiate and sustain. Accordingly, it is more readily accepted by college students and can be more easily integrated into their daily lives.

An interesting finding is that vigorous-intensity physical activity may be positively associated with the incidence of depressive symptoms. This result is supported by evidence from Chinese family panel studies. Teenagers who reported engaging in more vigorous physical activity experienced significantly higher risks of depressive symptoms than their peers who reported having little or no vigorous physical activity [31]. This might be attributable to the fact that vigorous physical activity induces greater perceived stress and elevates the levels of pro-inflammatory cytokines in the body [32]. Previous studies also reported that vigorous physical activity may lead to negative self-perception, sleep disorders, or loss of appetite [33], thereby inducing depressive symptoms. Both national and international physical activity guidelines consistently recommend that adults engage in at least 150 min of moderate-intensity exercise or 75 min of vigorous exercise per week, or a combination of both equivalent to the above recommendations [34,35] to achieve health-promoting benefits. These recommendations are primarily based on large-scale epidemiological studies examining the relationship between physical activity and outcomes such as all-cause mortality or cardiometabolic factors (including cardiovascular disease, blood pressure, blood lipids, blood glucose, and insulin levels) rather than on outcomes related to mental health. By contrast, the findings of this study revealed that physical activity with higher intensity may not necessarily contribute to better mental health. Low- to moderate-intensity physical activity may be more effective in preventing mental health issues, such as depressive symptoms. Therefore, compared with physical health, mental health may have different needs on physical activity intensity. As there are currently no exercise guidelines for mental health, further studies are warranted to explore specialized physical activity guidelines.

Overall, the association between physical activity intensity and depressive symptoms may be explained by some interrelated psychological and behavioral mechanisms. First, from the stress regulation, varying intensities of physical activity might differentially impact physiological stress responses differently. Vigorous-intensity physical activity could potentially trigger increased stress activation, consequently affecting mood adversely, whereas low- to moderate-intensity physical activity might facilitate stress reduction and enhance mood [36]. Second, according to behavioral activation theory, engagement in low- to moderate-intensity physical activity,

particularly within group settings, can augment accomplishments and exposure to rewarding experiences [37]. Furthermore, physiological mechanisms research found that low- to moderate-intensity activity improves mood by promoting the release of dopamine and endorphins, while high-intensity activity increases the risk of depression by increasing cortisol and pro-inflammatory factors [38].

This study has some limitations as follows. First, a self-report scale was used to measure physical activity, which might have caused memory bias among participants. Using an accelerometer to evaluate physical activity may better reflect actual physical activity levels. Second, as the single-center sample and high proportion of female participants may limit the generalizability of the results to universities with a high proportion of male students, future studies should adopt multi-center and gender-balanced samples. Third, despite adjusting for several confounders in the multivariate analyses, other potential confounders may have influenced the outcomes. More lifestyle or physical fitness related factors should be further controlled for to further lower the possibility of confounding in the analysis. Finally, the causality and underlying mechanisms of the findings could not be identified because of the use of an observational study design. Subsequent experimental work is thus necessary to confirm these findings.

5 Conclusions

In summary, this study has provided crucial evidence that the association between physical activity and depressive symptoms among college students is not uniform but is dependent on activity intensity. As hypothesized, our study demonstrated that the association between physical activity and depressive symptoms varies by intensity level, with low- and moderate-intensity physical activity being correlated with a lowered risk of depressive symptoms, and vigorous-intensity physical activity tending to be associated with an increased incidence. It is recommended that college students engage in $\geq$133 min of low-intensity activities or $\geq$107 min of moderate-intensity activities per week to improve their mental health. There is thus an urgent need to further optimize the physical activity strategies for maintaining the mental health of the college students, and to clearly distinguish the differences in the associations of various physical activity intensities with physical health and mental health. Mental health interventions on campus could integrate structured, moderate-intensity programs as low-barrier, cost-effective supplements to traditional counseling. Current physical activity guidelines for young adults, which often emphasize total volume or vigorous exercise for cardiorespiratory fitness, may require refinement. Moreover, longitudinal and experimental studies are warranted to understand the causal relationship between physical activity intensity and depressive symptoms and the underlying mechanisms. Finally, intervention studies that directly compare the mental health outcomes of different physical activity intensity programs are needed to inform evidence-based guidelines that distinguish physical health promotion goals from mental health promotion goals.

Acknowledgement: The authors thank all the participants of this study.

Funding Statement: This work was funded by the Ministry of Education of Humanities and Social Science project, China [18YJCZH053].

Author Contributions: Conceptualization, Yan Huang and Guang Yang; methodology, Yan Huang, Yongjin Xu and Chunchun Wu; software, Yan Huang and Guang Yang; validation, Yan Huang, Yongjin Xu, Chunchun Wu and Guang Yang; formal analysis, Yan Huang and Yongjin Xu; investigation, Yongjin Xu and Chunchun Wu; resources, Guang Yang; data curation, Yan Huang and Yongjin Xu; writing—original draft preparation, Yan Huang, Yongjin Xu, Chunchun Wu and Guang Yang; supervision, Guang Yang; project administration, Guang Yang; funding acquisition, Guang Yang. All authors reviewed and approved the final version of the manuscript.

Availability of Data and Materials: Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Ethics Approval: The study included human subjects. This study was part of a larger project led by Zhejiang University (the Fitness Improvement Tactics in Youth Project), and the research protocol was approved by the Institutional Review Board of Zhejiang University (No. 2021[004]). Written informed consent was obtained from each participant.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

ANOVA	Analysis of Variance
BMI	Body Mass Index
CI	Confidence Intervals
IPAQ	International Physical Activity Questionnaire
LMPA	Low- to Moderate-Intensity Physical Activity
MetS	Metabolic Syndrome
METs	Metabolic Equivalents of Task
MVPA	Moderate- to Vigorous-Intensity Physical Activity
OR	Odds Ratios
SDS	Zung Self-Rating Depression Scale
VIF	Variance Inflation Factors

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