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Associations Between Moderate- and Vigorous-Intensity Leisure-Time Physical Activity and Depressive Symptoms Among First-Year University Students: A One-Year Longitudinal Study

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Abstract

This study conducted a four-wave longitudinal survey over one academic year to examine the associations between moderate- and vigorous-intensity leisure-time physical activity (LTPA) and depressive symptoms among first-year university students, as well as potential gender differences. A total of 456 freshmen (M_{age} = 18.18, SD = 0.67; 202 males and 254 females) participated in the study. Data were analyzed using latent growth modeling. Results revealed that depressive symptoms were relatively high at the beginning of the first year but showed a slight decline over time, whereas overall LTPA demonstrated an upward trajectory across the academic year. Parallel process latent growth model indicated that vigorous-intensity LTPA was significantly associated with lower levels of depressive symptoms (β = -0.441, p = 0.002), whereas the association for moderate-intensity LTPA was not statistically significant (β = -0.278, p = 0.071). Additionally, female students exhibited significantly lower baseline levels of both moderate- and vigorous-intensity LTPA compared to males; however, gender did not moderate the associations between LTPA and depressive symptoms. These findings highlight the importance for universities and public health practitioners to design interventions that are stage-specific, intensity-matched, and sensitive to gender-related participation barriers.

Trial registration

Clinical trial number: not applicable.

1. Introduction

The early stage of university life represents a critical transitional period that is often accompanied by multiple challenges. During this time, students must adapt to new academic, social, and personal environments while managing academic pressure, psychological and physiological changes, lifestyle adjustments, and the reorganization of interpersonal and family relationships (Huang et al., 2025; Li et al., 2022; X.-Q. Liu et al., 2022; Sheldon et al., 2021). Without effective coping mechanisms, students are particularly vulnerable to elevated levels of depressive symptoms. Globally, the prevalence of depression among university students remains alarmingly high. A large-scale meta-analysis reported a pooled prevalence of 33.6%, with the highest rates observed in Africa (40.1%), followed by Asia (34.8%) and North America (35.5%) (Li et al., 2022). Among young adults, depression is a major contributor to years lived with disability and disability-adjusted life years (Mokdad et al., 2016) and is strongly associated with premature mortality and suicidal behaviors (Walker et al., 2015; Patel et al., 2016.). Consequently, identifying effective strategies to mitigate depressive symptoms has become an urgent public health priority.

Physical activity (PA), as a positive health behavior, has been widely recognized as an effective means of reducing the risk of depressive symptoms (Rodriguez-Ayllon et al., 2019; Schuch et al., 2016, 2018). Compared with traditional psychotherapeutic or pharmacological interventions, PA offers distinct advantages—such as accessibility, low cost, and minimal side effects—making it particularly suitable for university populations. Mounting evidence suggests that the beneficial effects of PA on mental health are driven by both psychosocial and neurophysiological mechanisms (Singh et al., 2023; Lubans et al., 2016a). From a psychosocial perspective, engaging in diverse physical activities may enhance self-regulation and alleviate stress (Lubans et al., 2016). From a neurophysiological standpoint, PA improves depressive symptoms through multiple biological pathways, including the upregulation of neurotrophic factors, increased availability of serotonin and norepinephrine, and reduced systemic inflammation (Gujral & Butters et al., 2017; Lubans et al., 2016). Moreover, participation in PA enhances adolescents' physical self-perception, self-worth, and self-esteem (Lubans et al., 2016a), all of which contribute to better emotional well-being.

Empirical findings have provided strong support for the antidepressant effects of PA. A systematic review encompassing 49 prospective cohort studies with 266,939 participants demonstrated a significant association between higher levels of PA and a reduced risk of depression across age groups and geographical regions (Schuch et al., 2018). Similarly, a meta-analysis of 25 randomized controlled trials (RCTs) found that PA exerted a significant antidepressant effect compared with control conditions (Schuch et al., 2016). In addition, a comprehensive review and meta-analysis of 114 original studies —including both intervention and observational designs—revealed that PA interventions significantly improved adolescents' mental health and that PA was inversely associated with depressive symptoms (Rodriguez-Ayllon et al., 2019). Collectively, these findings underscore the preventive and therapeutic potential of PA in reducing depressive symptomatology.

Despite this strong evidence base, the optimal "dose" of PA remains an open question. Most studies have treated PA as a single construct without differentiating between intensity levels, making it difficult to determine which intensity is most effective for reducing depressive symptoms. Paolucci et al. (2018) found that moderate-intensity PA reduced depression, anxiety, and perceived stress by lowering proinflammatory cytokines,whereas vigorous-intensity PA—despite its antidepressant potential—might increase perceived stress and inflammation due to heightened physiological strain. In contrast, VanKim and Nelson (2013) reported that vigorous-intensity PA was associated with better mental health and lower perceived stress among university students, potentially through enhanced social interactions. Interestingly, Dishman et al. (2021) observed that both moderate- and vigorous-intensity PA were strongly correlated with lower depression risk. These inconsistent findings highlight the need for more nuanced research to clarify how PA intensity relates to depressive symptoms.

Gender is another key demographic factor that may shape the relationship between PA and mental health, yet empirical findings remain mixed. Some studies suggest that males derive greater benefits from PA, as they tend to engage more actively in physical activities that facilitate emotional regulation (Liu et al., 2024). Conversely, other research indicates that regular PA may provide stronger benefits for females experiencing mild to moderate depression (Zhang & Yen, 2015). These inconsistencies underscore the need to examine whether gender moderates the association between PA and depression trajectories, particularly during early university life when gender-related socialization patterns and stress responses may diverge.

Although previous studies have provided some evidence for the association between physical activity (PA) and depression, the question of how different intensities of PA influence the trajectory of depressive symptoms among first-year college students—a population undergoing a critical transition—remains unresolved. Most existing studies have adopted cross-sectional designs or single-variable analyses, which fail to capture the longitudinal interplay between

the two variables and overlook potential associations between their initial levels and rates of change. The parallel process latent growth model (PP-LGM) offers a methodological advantage in this regard, as it simultaneously estimates the initial levels and growth rates of both depression and different intensities of PA. By examining the associations between these latent variables, the PP-LGM can reveal the dynamic relationships between their developmental trajectories, thereby addressing the limitations of previous longitudinal studies and providing a robust analytical framework for understanding the complex "PA–depression" relationship.

Given the inconsistent findings regarding PA intensity and the unclear role of gender moderation, the present study aims to examine the dynamic associations between depressive symptoms and leisure-time physical activity (LTPA) of different intensities among first-year university students. Specifically, this study addresses two central questions: (1) What are the initial levels and developmental trajectories of depressive symptoms and LTPA among first-year students? and (2) How do the initial levels and rates of change in to overall LTPA, vigorous-intensity PA, and moderate-intensity PA influence depressive symptoms over time? Based on prior evidence suggesting that moderate-intensity PA has stronger links to mental health, we hypothesize that overall LTPA will be negatively associated with the initial level of depressive symptoms, with moderate-intensity LTPA showing a stronger relationship. Furthermore, we hypothesize that gender moderates the associations between all intensities of LTPA and the trajectories of depressive symptoms.

2. Methods

2.1. Participants and procedures

Participants were first-year undergraduate students from a comprehensive university in Central China, representing a range of academic disciplines including education, literature, engineering, management, and the arts. Ethical approval for this study was obtained from the Ethics Committee (Institutional Review Board, IRB) of Central China Normal University (approval no. CCNU-IRB-202509002A). Informed consent was obtained electronically from all participants prior to participation. Before completing the online questionnaire, participants were provided with detailed information about the purpose of the study, the voluntary nature of participation, and assurances of confidentiality and anonymity. Only participants who indicated their consent by selecting the consent option proceeded to the survey. All questionnaires were completed online during scheduled sessions and submitted immediately upon completion.This study adopted a one academic year longitudinal research design with four waves across two semesters, and data were collected at three-month intervals to fully capture temporal changes. Specifically, data for T1 and T2 were collected in the first week and the last week of the first semester, respectively, while data for T3 and T4 were collected in the first week and the last week of the second semester, respectively.The time spacing between each wave was designed to balance sensitivity to developmental change with the need to minimize respondent burden. The procedure was identical across all measurement occasions, and each assessment took approximately 15 minutes to complete. No participants reported difficulties in understanding the questionnaire items at any wave. At the first wave (T1), questionnaires were distributed to 456 students (N = 456), yielding 381 valid responses; at T2, 426 responses were obtained; at T3, 390 responses; and at T4, 452 responses.This study allowed students who did not participate in a particular measurement to continue taking part in subsequent surveys. Across the four waves of data collection, a total of 1,649 valid questionnaires were obtained. Participants' mean age was 18.18 years (SD = 0.67), with 202 males and 254 females.To assess the pattern of missing data, Little's MCAR test was conducted, yielding nonsignificant results (χ^2 = 26.33, df = 24, p > .05), indicating that the data were missing completely at random (MCAR). In accordance with recommendations by Duncan et al. (1998) and Chen et al. (2020), missing data were handled using maximum likelihood estimation with robust standard errors MLR in subsequent analyses.

2.2. Measures

2.2.1. Depressive symptoms

Depressive symptoms were assessed using the Chinese version of the Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001), a widely used self-report instrument designed to evaluate the presence and severity of depressive symptoms. The PHQ-9 consists of nine items, each corresponding to the core diagnostic criteria for major depressive disorder outlined in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV). Participants were instructed to respond to the question:"During the past two weeks, how often have you been bothered by the following problems in your daily life?"Responses were recorded on a 4-point Likert-type scale ranging from 0 (not at all) to 3 (nearly every day). Total scores range from 0 to 27, calculated as the sum of all item scores, with higher scores indicating more severe depressive symptoms. Following the classification proposed by Paolucci et al. (2018), depressive symptom severity was categorized into five levels: minimal (0–4), mild (5–9), moderate (10–14), moderately severe (15–19), and severe (20–27).

The PHQ-9 has demonstrated robust psychometric properties across diverse populations, and the Simplified Chinese version has been validated among both adolescents and adults, exhibiting excellent reliability and validity (Leung et al., 2020; Tsai et al., 2014). In the present study, the PHQ-9 showed high internal consistency across all four waves (α = .880 at T1; α = .908 at T2; α = .921 at T3; α = .938 at T4).

2.2.2. Leisure-Time Physical Activity (LTPA)

Leisure-time physical activity (LTPA) was measured using the Godin–Shephard Leisure-Time Physical Activity Questionnaire (GSLTPAQ; Godin et al., 1997), a widely adopted instrument for assessing habitual physical activity in free time. The questionnaire consists of two parts.In the first section, participants were asked:

During a typical week in your leisure time, how many times (for more than 30 minutes each) do you engage in the following types of physical activity? Please indicate the activities you perform and the frequency of participation.

This section classifies physical activity into three intensity levels according to the degree of exertion:Vigorous-intensity LTPA (e.g., basketball, soccer) — activities that cause rapid heartbeat and heavy breathing;Moderate-intensity LTPA (e.g., casual swimming, dancing) — activities that increase breathing rate but do not cause exhaustion;Light-intensity LTPA (e.g., yoga, walking) — activities that require minimal physical effort.The second section assessed

participants' general engagement in LTPA during college, with frequency options ranging from "never" to "almost every day." This part served as a validity check to identify potential inconsistencies in self-reported LTPA frequency from the first section.For scoring, each intensity level was assigned a metabolic equivalent task (MET) value—9 for vigorous, 5 for moderate, and 3 for light activity. The MET value was multiplied by the reported frequency of each intensity level, and the three products were then summed to yield a overall LTPA score. Total scores typically range from 0 to 119, with higher scores indicating greater levels of leisure-time physical activity.The GSLTPAQ has demonstrated good reliability and validity when compared with objective measures such as accelerometer data and maximal oxygen uptake (VO_2max) (Amireault & Godin, 2015; Godin, 2011). In the present study, the LTPA scale showed acceptable internal consistency across all four waves (α = .714 at T1; α = .778 at T2; α = .796 at T3; α = .762 at T4).

2.3. Statistical analysis

Statistical analyses were conducted in several sequential steps. First, SPSS 26.0 was used to perform descriptive statistics, repeated-measures analyses of variance (ANOVA), and correlation analyses to examine the distributional characteristics of all variables and their interrelationships. Next, Mplus 8.3 was employed to construct unconditional latent growth models (LGM) for depressive symptoms, overall leisure-time physical activity (LTPA), and different intensities of LTPA, in order to explore their developmental trajectories over time. Latent growth modeling is a widely used approach for examining the longitudinal trajectories of a single variable (Meredith & Tisak, 1990). In this framework, the intercept factor represents the initial level of the construct, while the slope factor reflects its rate of change over time. Subsequently, PP-LGM were estimated to evaluate the associations between the growth components (i.e., intercepts and slopes) of depressive symptoms and LTPA. In the PP-LGM framework, the previously established univariate LGM were incorporated into a single integrated model to assess the dynamic relationships among the latent intercepts and slopes of all variables, while gender was included as a covariate. Model fit was evaluated using multiple goodness-of-fit indices, including the chi-square to degrees of freedom ratio (χ^2/df), the Comparative Fit Index (CFI), the Tucker–Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). Model fit was considered acceptable when CFI and TLI values exceeded 0.90, and good when both were greater than 0.95. Values of RMSEA below 0.08 and SRMR below 0.06 were also indicative of a good model fit (Hu & Bentler, 1999).

3. Results

3.1. Descriptive statistics and correlation analysis

A repeated-measures ANOVA was first conducted to examine the main effects of time, gender, and their interaction on the study variables. For depressive symptoms, Mauchly's test of sphericity indicated a violation of the sphericity assumption ($W = 0.938$, $p < .05$); therefore, the Greenhouse–Geisser correction was applied. The results revealed a significant main effect of time ($F = 6.953$, $p < .001$), while neither the main effect of gender ($F = 1.348$, $p > .05$) nor the interaction effect between time and gender ($F = 1.542$, $p > .05$) reached significance. Similarly, for LTPA, Mauchly's test also indicated that the assumption of sphericity was violated ($W = 0.819$, $p < .001$), and thus the Greenhouse–Geisser correction was used. The results showed a significant main effect of time ($F = 25.432$, $p < .001$) and a significant main effect of gender ($F = 57.419$, $p < .001$), but the interaction effect between time and gender was not significant ($F = 0.659$, $p > .05$).

As shown in Table 1, the mean scores for depressive symptoms (DS) fluctuated across the four time points, with standard deviations ranging from 4.71 to 4.90, suggesting a slight increase in interindividual variability. The mean score of overall LTPA showed a continuous upward trend, while its standard deviation first decreased and then increased, indicating that students' overall participation in leisure-time physical activity improved over time, with intra-group differences narrowing initially and slightly widening later. Both vigorous- and moderate-intensity LTPA displayed similar trends—mean levels increased steadily, and standard deviations decreased before rising again—suggesting that participation in both activity intensities increased, with temporal fluctuations in within-group variability.

Table 2 presents the correlations between depressive symptoms (DS) and overall LTPA, vigorous-intensity LTPA, and moderate-intensity LTPA across the four measurement occasions. Overall, depressive symptoms were negatively correlated with different intensities of LTPA at most time points. Specifically, overall LTPA and vigorous-intensity LTPA exhibited consistent and significant negative correlations with depressive symptoms across most waves, whereas correlations with moderate-intensity LTPA were weaker or nonsignificant, particularly at T2 and T4. These findings suggest that higher levels of physical activity—especially vigorous-intensity LTPA—are generally associated with lower depressive symptoms, although the strength of this association appears to vary across time and activity intensity, warranting further longitudinal verification.

Table 1
Descriptive Statistics for Depressive Symptoms and Different Intensities of Leisure-Time Physical Activity.

		Time1	Time2	Time3	Time4
	Range	M/SD	M/SD	M/SD	M/SD
DS	0–27	5.89/4.71	6.28/4.62	5.45/4.69	5.60/4.90
Overall LTPA	0-119	42.57/24.69	50.15/20.02	50.45/20.59	55.76/23.44
V-LTPA	0–63	20.53/15.44	25.56/12.78	25.64/13.18	28.10/14.66
M-LTPA	0–35	12.87/8.69	14.91/6.35	15.21/6.60	16.13/8.00

Note: Overall LTPA = Overall Leisure-Time Physical Activity; V-LTPA = vigorous-intensity Leisure-Time Physical Activity; M-LTPA = moderate intensity Leisure-Time Physical Activity; DS = depression symptoms.

Table 2
Correlations Between Depressive Symptoms and Different Intensities of Leisure-Time Physical Activity.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DS_{T1}	1														
DS_{T2}	.438**	1													
DS_{T3}	.393**	.555**	1												
DS_{T4}	.357**	.501**	.576**	1											
Overall $LTPA_{T1}$	− .134**	− .173**	− .122*	− .161**	1										
Overall $LTPA_{T2}$	− .130*	− .119*	− .091	− .096*	.296**	1									
Overall $LTPA_{T3}$	− .170**	− .127*	− .174**	− .158**	.162**	.392**	1								
Overall $LTPA_{T4}$	− .061	− .052	− .059	− .106*	.131*	.223**	.284**	1							
V-$LTPA_{T1}$	− .145**	− .156**	− .153**	− .182**	.895**	.255**	.180**	.134**	1						
V-$LTPA_{T2}$	− .140**	− .169**	− .122*	− .075	.288**	.925**	.377**	.244**	.266**	1					
V-$LTPA_{T3}$	− .167**	− .128*	− .168**	− .140**	.169**	.397**	.925**	.269**	.197**	.411**	1				
V-$LTPA_{T4}$	− .112*	− .056	− .081	− .108*	.157**	.223**	.271**	.911**	.171**	.251**	.290**	1			
M-$LTPA_{T1}$	− .095	− .131*	− .062	− .136**	.813**	.216**	.085	.152**	.536**	.193**	.069	.151**	1		
M-$LTPA_{T2}$	− .044	.003	.027	− .067	.200**	.805**	.284**	.125*	.152**	.571**	.246**	.095	.161**	1	
M-$LTPA_{T3}$	− .116*	− .058	− .111*	− .131*	.07	.249**	.807**	.235**	.079	.189**	.562**	.182**	.066	.259**	1
M-$LTPA_{T4}$	.034	− .026	− .016	− .057	.071	.115*	.182**	.825**	.081	.116*	.143**	.571**	.098	.101*	.195**

Note: Overall LTPA = Overall Leisure-Time Physical Activity; V-$LTPA_{TI-T4}$ = vigorous-intensity Leisure-Time Physical Activity Time1-4; M-$LTPA_{T1-T4}$ =moderate-intensity Leisure-Time Physical Activity Time1-4; DS_{TI-T4}=depression symptoms Time 1–4.

**p < .01, *p < .05.

3.2. Measurement invariance

Table 3 presents the results of the measurement invariance tests conducted for the depression scale, to ensure that the observed changes over time reflect true developmental changes rather than variations in the measurement structure across time points (Liao et al., 2022). In this study, a series of increasingly restrictive models were estimated to assess measurement invariance across the four time points, including configural invariance (equal factor structure), metric invariance (equal factor loadings), and scalar invariance (equal item intercepts). Given that the chi-square (χ^2) statistic is highly sensitive to sample size, changes in fit indices (ΔCFI, ΔTLI, and ΔRMSEA) were used to evaluate invariance between the configural and more constrained models (Cheung & Rensvold, 1999). Measurement invariance was considered to be established when ΔCFI and ΔTLI were both less than 0.01, and ΔRMSEA was less than 0.015.

Table 3
Fit Statistics for Measurement Invariance Testing of Depressive Symptoms.

Model	χ^2	*df*	CFI	ΔCFI	TLI	ΔTLI	RMSEA	ΔRMSEA
Configural	1148.381*	534	0.943	-	0.932	-	0.042	-
Weak	1200.231*	558	0.941	-0.002	0.934	0.002	0.042	0
Strong	1255.100*	582	0.937	-0.004	0.932	-0.002	0.042	0

Note. CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation.

3.3. Unconditional Growth Model

In this study, separate univariate unconditional growth models were constructed for depressive symptoms, overall LTPA, vigorous-intensity LTPA, and moderate-intensity LTPA. Overall model fit information and parameter estimates for the intercept and slope components are presented in Table 4. First, an unconditional linear growth model was established for depressive symptoms. The model demonstrated a good fit to the data ($\chi^2/df = 2.515$, CFI = 0.977, TLI = 0.972, RMSEA = 0.045, SRMR = 0.033). According to the parameter estimates, the initial level of depressive symptoms was 1.949 (SE = 0.195, $p < .001$), indicating that, on average, freshmen exhibited a mild level of depressive symptoms at the beginning of the first semester, with significant inter-individual variability. The mean slope was − 0.183 (SE = 0.101, $p > .05$), suggesting a slight decreasing trend in depressive symptoms over time. The correlation between the intercept and slope was not significant ($r = - 0.096$, $p > .05$), implying that the initial level of depressive symptoms was not associated with the rate of change.

Next, unconditional linear and quadratic growth models were fitted for overall LTPA, but both showed unsatisfactory model fit. Subsequently, a freely estimated latent basis model was tested by fixing the slope loadings for the first two time points to 0 and 1, and allowing the last two loadings to be freely estimated. The resulting model fit indices ($\chi^2/df = 3.461$, CFI = 0.941, TLI = 0.882, RMSEA = 0.071, SRMR = 0.039) indicated suboptimal fit as TLI was below 0.90.To improve model fit, a constrained latent basis model was estimated, fixing the slope loadings at 0, 1, 1.2, and 1.8 for the four time points. This model demonstrated good fit ($\chi^2/df = 2.090$, CFI = 0.962, TLI = 0.955, RMSEA = 0.044, SRMR = 0.039) and was therefore retained as the final model.

Results showed that the mean initial level of overall LTPA was 2.923 (SE = 0.386, $p < .001$), and the mean slope was 0.920 (SE = 0.249, $p < .001$), indicating that students' engagement in leisure-time physical activity increased significantly across the academic year. The non-linear pattern of slope factor loadings suggests that the rate of increase was not constant over time. The correlation between the intercept and slope was significant and negative ($r = - 0.610$, $p < .001$), implying that students with lower initial levels of LTPA tended to show greater increases over time.

3.4. Unconditional Growth Model for Moderate-Intensity LTPA

Unconditional linear and quadratic growth models were first constructed for moderate-intensity LTPA; however, both models yielded unsatisfactory fit indices. Subsequently, a freely estimated latent basis model was tested, fixing the slope loadings for the first two time points to 0 and 1, while allowing the last two loadings to be freely estimated. The model fit indices ($\chi^2/df = 2.329$, CFI = 0.924, TLI = 0.847, RMSEA = 0.045, SRMR = 0.034) indicated that the model fit remained suboptimal, as TLI was below the recommended cutoff of 0.90. Based on the freely estimated loadings (0, 1, 1.223, and 1.583), a constrained latent basis model was then specified, fixing the slope loadings at 0, 1, 1.5, and 2 across the four measurement points. The revised model demonstrated a good overall fit ($\chi^2/df = 1.677$, CFI = 0.948, TLI = 0.938, RMSEA = 0.029, SRMR = 0.036) and was therefore retained as the final model.

Parameter estimates revealed that the mean initial level of moderate-intensity LTPA among freshmen was 3.718 (SE = 0.887, $p < .001$), while the mean slope was 0.864 (SE = 0.394, $p < .05$), indicating a significant upward trajectory over the academic year. The non-linear pattern of the slope loadings suggests that the rate of increase in moderate-intensity LTPA was not constant, implying accelerated engagement in such activities during later stages of the year. Moreover, the correlation between the intercept and slope was significantly negative ($r = - 0.563$, $p < .05$), suggesting that students who initially engaged less in moderate-intensity LTPA exhibited greater increases in participation over time.

3.5. Unconditional Growth Model for Vigorous-Intensity LTPA

Unconditional linear and quadratic growth models were first constructed for vigorous-intensity LTPA; however, both models exhibited unsatisfactory fit indices. To improve model performance, a freely estimated latent basis model was then tested, with slope loadings for the first two time points fixed at 0 and 1, and the remaining two loadings freely estimated. The resulting model fit indices ($\chi^2/df = 2.626$, CFI = 0.967, TLI = 0.935, RMSEA = 0.051, SRMR = 0.037) indicated that, although fit was acceptable overall, the 90% confidence interval (CI) of RMSEA exceeded 0.10, suggesting that further refinement was warranted. Based on the freely estimated slope loadings (0, 1, 1.058, and 1.485), a constrained latent basis model was subsequently specified by fixing the four slope loadings to 0, 1, 1.1, and 1.5, respectively. This revised model achieved a strong overall fit ($\chi^2/df = 1.592$, CFI = 0.985, TLI = 0.981, RMSEA = 0.027, SRMR = 0.038) and was therefore retained as the final model for vigorous-intensity LTPA.

Model estimates revealed that the mean initial level of vigorous-intensity LTPA among first-year students was 2.478 (SE = 0.567, $p < .001$), indicating relatively low engagement at the beginning of the academic year. The mean slope was 1.173 (SE = 0.717, $p > .05$), suggesting a non-significant upward trend in participation over time. Consistent with the pattern of the slope loadings, the rate of change in vigorous-intensity LTPA was non-linear, implying that increases in participation did not occur at a uniform pace. The correlation between intercept and slope was negative but non-significant ($r = - 0.447$, $p > .05$), indicating that students' initial levels of vigorous-intensity activity were not systematically related to the rate of change in their subsequent trajectories.

Table 4
Overall Model Fit, Level, and Slope Trajectories for the Growth Models

Estimates of parameters	Depression	Overall Leisure-Time Physical Activity	Vigorous-intensity LTPA	Moderate-intensity LTPA
Means				
Intercept	1.949*(.195)	2.923*(.000)	2.478*(.000)	3.718*(.000)
Slope	-0.183(.101)	0.920*(.000)	1.173(.102)	0.864*(.028)
Correlation				
r	-0.096(.680)	-0.610*(.000)	-0.447*(.207)	-0.563*(.025)
Fit of the model				
	χ^2/df = 2.515	χ^2/df = 2.090	χ^2/df = 1.592	χ^2/df = 1.667
	p = 0.0845	p = 0.0948	p = 0.2426	p = 0.2298
	CFI = 0.977	CFI = 0.962	CFI = 0.985	CFI = 0.948
	TLI = 0.972	TLI = 0.955	TLI = 0.981	TLI = 0.938
	RMSEA = 0.045	RMSEA = 0.044	RMSEA = 0.027	RMSEA = 0.029
	90% CI: 0-0.088	90% CI: 0-0.087	90% CI: 0-0.075	90% CI: 0-0.076

Note: Standard errors are in parentheses.

**p < .01, *p < .05.

3.6. Parallel Process Latent Growth Model

3.6.1. PP-LGM of Depression and Overall LTPA

Next, the unconditional latent growth models for depression and overall LTPA were integrated to construct an unconditional parallel process latent growth model aiming to further examine the associations between the two constructs over time. The PP-LGM demonstrated an excellent overall fit (χ^2/df = 1.382, CFI = 0.989, TLI = 0.987, RMSEA = 0.021, 90% CI [0.000, 0.047], SRMR = 0.034). The covariances between the intercepts and slopes of the two variables revealed several key patterns. Specifically, the initial level of depression significantly and negatively predicted the initial level of overall LTPA (β = −0.388, p = .001), suggesting that students with higher baseline depressive symptoms tended to engage in lower levels of LTPA. However, the predictive effect of the initial level of depression on the rate of change in LTPA was not statistically significant (β = 0.219, p = .196), indicating that baseline depression did not substantially influence the trajectory of LTPA over time. Likewise, the initial level of LTPA did not significantly predict changes in depression (β = 0.031, p = .828). The covariance between the slopes of depression and LTPA was also nonsignificant (β = −0.140, p = .512), implying that changes in the two constructs were not synchronized across time.

3.6.2. Incorporating Gender as a Time-Invariant Covariate

Building upon the baseline PP-LGM, gender was included as a time-invariant covariate to explore its potential moderating effects. The results indicated that gender did not significantly predict either the initial level (β = 0.059, p = .391) or the rate of change (β = 0.101, p = .299) of depression. However, gender had a significant negative effect on the initial level of LTPA (β = −0.385, p < .001), indicating that female students reported substantially lower initial levels of LTPA than their male counterparts. Gender did not significantly predict the rate of change in LTPA (β = 0.033, p = .750). Furthermore, the initial levels of depression and LTPA were found to be significantly negatively correlated (r = − 0.391, p = .001), suggesting that students with higher baseline depressive symptoms tended to participate less in leisure-time physical activity at the outset.

3.6.3. PP-LGM of Depression and Moderate-Intensity LTPA

Next, the unconditional latent growth models for depression and moderate-intensity LTPA were integrated to construct an unconditional parallel process latent growth model, aiming to further explore the longitudinal associations between these two variables. The model demonstrated a good overall fit (χ^2/df = 1.489, CFI = 0.985, TLI = 0.981, RMSEA = 0.023, 90% CI [0.000, 0.047], SRMR = 0.039). The covariance results between the intercepts and slopes of the two constructs revealed that the initial level of depression was negatively but not significantly associated with the initial level of moderate-intensity LTPA (β = −0.278, p = .071). The initial level of depression did not significantly predict the rate of change in moderate-intensity LTPA (β = 0.269, p = .257), indicating that baseline depressive symptoms did not exert a substantial influence on the trajectory of moderate-intensity physical activity over time. Similarly, the initial level of moderate-intensity LTPA did not significantly predict changes in depression (β = −0.073, p = .715), and the covariance between the slopes of depression and moderate-intensity LTPA was also nonsignificant (β = −0.187, p = .508), suggesting that changes in the two constructs were not dynamically coupled.

When gender was added as a time-invariant covariate, the results indicated that gender did not significantly predict either the initial level (β = 0.060, p = .383) or the rate of change (β = 0.099, p = .309) of depression. However, gender had a significant negative effect on the initial level of moderate-intensity LTPA (β = −0.381, p = .001), indicating that female students exhibited significantly lower initial levels of moderate-intensity LTPA compared with male students. Gender did not significantly influence the rate of change in moderate-intensity LTPA (β = 0.058, p = .681). Additionally, the initial levels of depression and moderate-

intensity LTPA were negatively correlated but not statistically significant (r = − 0.274, p = .100). Similarly, the slopes of depression and moderate-intensity LTPA were not significantly correlated (r = − 0.187, p = .484), indicating that the longitudinal changes in the two constructs were largely independent over time.

3.6.4. PP-LGM of Depression and Vigorous-Intensity LTPA

Next, the unconditional latent growth models for depression and vigorous-intensity LTPA were integrated to construct an unconditional parallel process latent growth model, with the goal of further examining the longitudinal association between depression and high-intensity leisure-time physical activity. The overall model demonstrated an excellent fit ($\chi^2/df = 1.378$, CFI = 0.990, TLI = 0.987, RMSEA = 0.021, 90% CI [0.000, 0.047], SRMR = 0.033).

The covariance estimates between the intercepts and slopes indicated that the initial level of depression was significantly and negatively associated with the initial level of vigorous-intensity LTPA (β = −0.441, p = .002), suggesting that students with higher baseline depressive symptoms tended to engage in less vigorous-intensity physical activity at the beginning of the study. However, the initial level of depression did not significantly predict the rate of change in vigorous-intensity LTPA over time (β = −0.198, p = .373), indicating that baseline depression did not substantially influence the rate at which vigorous-intensity physical activity changed. Similarly, the initial level of vigorous-intensity LTPA did not significantly predict changes in depression (β = −0.020, p = .895), and the covariance between the slopes of depression and vigorous-intensity LTPA was also nonsignificant (β = −0.061, p = .823), suggesting a lack of dynamic interdependence between the two trajectories.

After including gender as a time-invariant covariate, the results showed that gender had no significant predictive effects on either the initial level (β = 0.058, p = .400) or the rate of change (β = 0.104, p = .289) of depression. However, gender significantly predicted the initial level of vigorous-intensity LTPA (β = −0.471, p < .001), indicating that female students engaged in significantly less vigorous-intensity physical activity at baseline compared with male students. Gender did not significantly predict the rate of change in vigorous-intensity LTPA (β = 0.150, p = .270). Moreover, after controlling for gender, the initial level of depression remained significantly and negatively correlated with the initial level of vigorous-intensity LTPA (r = − 0.453, p = .004), suggesting that individuals with higher initial depressive symptoms tended to exhibit lower levels of vigorous-intensity LTPA participation at the outset.Table 5 presents the correlation coefficients between depressive symptoms and different intensities of leisure-time physical activity in the parallel process latent growth model.

Table 5
Correlation Coefficients Between Depressive Symptoms and Different Intensities of Leisure-Time Physical Activity in the Parallel Process Latent Growth Model.

	Overall LTPA intercept	Overall LTPA slope	V-LTPA intercept	V-LTPA slope	M-LTPA intercept	M-LTPA slope
DS intercept	-0.388**	0.219	-0.441**	0.198	-0.332*	0.359
DS slope	0.031	-0.140	0.020	0.061	-0.070	-0.197

Note: Overall LTPA = Overall Leisure-Time Physical Activity; V-LTPA = vigorous-intensity Leisure-Time Physical Activity; M-LTPA = moderate intensity Leisure-Time Physical Activity; DS = depression symptoms.

**p < .01, *p < .05.

4. Discussion

The present study employed latent growth model to uncover the trajectories of depressive symptoms and leisure-time physical activity (LTPA) among first-year college students across one academic year, while also examining the moderating effects of activity intensity and gender. The findings revealed that first-year students exhibited a relatively high initial level of depression, which showed a marginally significant but slight downward trend over time. Moreover, the developmental trajectory of depressive symptoms demonstrated a nonlinear pattern, indicating that the rate of change in depression was not constant throughout the academic year. This finding is consistent with Sheldon et al. (2021), who noted that the transition to university represents a critical period of heightened vulnerability to depression. During this stage, students often face multiple, interrelated challenges—ranging from personal factors (e.g., low self-confidence, poor self-esteem) and lifestyle issues (e.g., unhealthy habits, poor sleep quality) to environmental stressors (e.g., academic pressure, financial difficulties) and insufficient social support (e.g., limited family or peer support) (X.-Q. Liu et al., 2022). These factors jointly contribute to emotional instability and increase the likelihood of depressive fluctuations among university freshmen. Taken together, these results underscore that first-year students constitute a high-risk population for depression, highlighting the urgent need for universities to strengthen mental health support systems and implement preventive interventions during the early stages of college life. Importantly, the significant variance observed in both the initial levels and rates of change of depressive symptoms suggests substantial individual differences in students' emotional adaptation. The absence of a significant correlation between the intercept and slope of depression further implies that the initial severity of depressive symptoms does not determine the pace of subsequent improvement. This insight provides valuable guidance for mental health promotion and policy design: regardless of students' baseline depression levels, timely interventions implemented at any stage of the first academic year may still be effective in alleviating depressive symptoms. Such evidence reinforces the importance of early screening, continuous monitoring, and targeted support programs for first-year students as part of a comprehensive university mental health framework.

The present study further examined the patterns of leisure-time physical activity (LTPA) among first-year university students. The results revealed that students generally reported low levels of LTPA at the beginning of college, but their engagement increased steadily over the course of the academic year. This trend suggests that students gradually adapt to university life and develop stronger motivation and capacity to participate in physical activity as time progresses. One of the most prominent barriers to LTPA among university students is a perceived lack of time (Brown et al., 2024). During the initial phase of university transition, first-year students often prioritize academic achievement above all else, believing that academic success requires intensive effort and

long study hours. Consequently, exercise is frequently the first activity sacrificed when time pressures arise (Hilger-Kolb et al., 2020). In addition, freshmen often struggle with ineffective time management and lifestyle adjustment during their early adaptation period, making it difficult to allocate consistent time for physical activity (Kwan & Faulkner, 2011). These factors collectively explain the low baseline level of LTPA observed at the start of the academic year. As the semester progresses, however, students appear to develop better coping strategies and integrate physical activity into their routines, resulting in a gradual increase in LTPA levels. This upward trajectory aligns with previous research showing that students tend to enhance both their motivation and self-efficacy for leisure-time exercise as they adapt to academic and social demands (Scarapicchia, Amireault et al., 2017; Scarapicchia, Sabiston et al., 2017).

A particularly noteworthy and practically meaningful finding of this study is that the initial level of LTPA was significantly negatively associated with its subsequent rate of change. In other words, students who started with lower levels of LTPA exhibited greater increases over time, whereas those with higher initial levels showed a more gradual rate of improvement. This “low-start, high-growth” and “high-start, slow-growth” pattern provides valuable insight for the precision design of university health interventions. Specifically, students with initially low LTPA should not be viewed as resistant to change, but rather as a group with greater potential for behavioral improvement and should thus be prioritized in intervention programs. Conversely, students with higher initial LTPA levels may require advanced or progressively challenging activities to sustain engagement and prevent dropout due to stagnation. Such differentiated approaches could optimize intervention outcomes and help universities design tiered strategies that promote long-term physical activity engagement across diverse student populations.

The results of the parallel process latent growth model examining depression and overall leisure-time physical activity (LTPA) revealed a significant negative correlation between the initial levels of depression and LTPA. Specifically, first-year students who reported higher depressive symptoms at college entry tended to exhibit lower levels of participation in LTPA. This finding is consistent with prior evidence showing a robust inverse association between physical activity and depressive symptoms (Rodriguez-Ayllon et al., 2019; Schuch et al., 2016, 2018). It suggests that students with greater depressive tendencies may be less motivated or less capable of maintaining regular engagement in physical activity during the early stages of university life. Notably, the results further indicated that the initial level of LTPA did not significantly predict the rate of change in depressive symptoms, and conversely, initial depressive levels did not significantly influence the rate of change in LTPA over time. This bidirectional non-significance pattern carries optimistic implications for intervention design: regardless of students’ initial levels of LTPA, subsequent increases in physical activity participation can still effectively alleviate depressive symptoms. In other words, the psychological benefits of LTPA appear to be state-independent—students who begin with either high or low activity levels can experience emotional improvement as long as their engagement in physical activity increases over time. This finding underscores the potential of targeted LTPA enhancement programs as a feasible and inclusive approach to depression prevention and reduction among university students.

A key contribution of the present study lies in the independent examination of vigorous and moderate intensity LTPA as predictors of depressive symptoms using parallel process latent growth model to capture their associations over time. The findings revealed a significant negative correlation between the initial level of depression and the initial level of vigorous intensity LTPA ($\beta = -0.44$, $p = 0.002$), whereas the association between depression and moderate intensity LTPA was negative but not statistically significant ($\beta = -0.278$, $p = 0.071$). Furthermore, after controlling for gender, only vigorous intensity LTPA remained significantly associated with depression, reinforcing the notion of a dose–response relationship in which higher intensity physical activity exerts stronger and more stable protective effects against depressive symptoms. This finding suggests that vigorous intensity LTPA plays a more pronounced role in mitigating depressive symptoms, which contrasts with some earlier studies (Paolucci et al., 2018; Huang et al., 2025) reporting comparable effects across intensity levels.

The significant association between vigorous intensity LTPA and reduced depressive symptoms can be explained through both biological and psychosocial mechanisms (Saucedo Marquez et al., 2015; Schuch et al., 2016). From a biological perspective, vigorous intensity LTPA more effectively stimulates the production of brain-derived neurotrophic factor (BDNF)—a critical molecule that enhances neuroplasticity and neural repair (Saucedo Marquez et al., 2015). BDNF helps restore structural and functional integrity in brain regions impaired by depression, such as the hippocampus and prefrontal cortex, thereby reversing neural atrophy and circuit dysfunction associated with depressive states. In addition, vigorous intensity LTPA may reduce excessive neural inhibition and enhance excitatory activity, counteracting the “underactivation” and “overinhibition” characteristic of depression (Andrews et al., 2020). Through these biological pathways, vigorous intensity LTPA contributes to sustained anti-inflammatory and neuroprotective environments that support long-term emotional stability (Kandola et al., 2019).

From a psychosocial perspective, the stronger link between vigorous intensity LTPA and reduced depression may stem from its enhanced social and self-perceptual benefits. Engaging in vigorous activities often involves team-based or group settings (e.g., basketball, soccer, collective training), where participants experience greater social interaction and peer support compared to moderate intensity activities (Li et al., 2022; Schuch et al., 2016). Such interactions foster a sense of belonging and companionship, which can alleviate loneliness and buffer against negative affect, thereby indirectly improving mental health outcomes (VanKim & Nelson, 2013). Moreover, vigorous intensity LTPA tends to enhance self-efficacy, body image, and self-esteem, which in turn promote better emotional regulation and resilience (Lubans et al., 2016b). Together, these psychosocial processes help explain why vigorous intensity LTPA demonstrates a stronger protective effect against depression relative to moderate intensity activity.

Another central aim of this study was to examine whether gender moderates the longitudinal association between LTPA and depressive symptom trajectories. The findings revealed that gender did not moderate the relationship between depression and LTPA at any intensity level. This result contrasts with previous evidence suggesting that men may derive greater mental health benefits from physical activity (Liu et al., 2024) or, conversely, that women may benefit more from such engagement (Zhang & Yen, 2015). After controlling for gender, the negative correlation between the initial levels of depression and LTPA remained significant across all intensities, indicating that this association is robust and independent of gender. In other words, regardless of being male or female, the general pattern of “higher LTPA → lower depression” consistently holds true (Dishman et al., 2021). Furthermore, gender appeared to influence the stability of LTPA trajectories, as the linear growth trend of LTPA became significant once gender was controlled, suggesting that gender should be treated as a critical covariate in longitudinal studies of physical activity.

Although gender did not moderate the link between LTPA and depression, its impact on the initial levels of LTPA was significant. Specifically, females reported lower baseline levels of total, vigorous, and moderate intensity LTPA than males, with the gender gap being most pronounced in vigorous intensity activities. This pattern aligns with previous studies (Sisay, 2021; Xu et al., 2021) showing that female students tend to engage less frequently in high-intensity or competitive physical activities. These findings underscore the need for universities to pay particular attention to promoting LTPA participation among female students (Chen et al., 2025). Developing low-barrier, inclusive, and female-oriented exercise programs—for example, group-based or skill-development activities—could encourage greater participation and help narrow the gender gap in campus physical activity. Overall, this evidence highlights the importance of incorporating gender considerations into the design and implementation of campus-based physical activity interventions to promote equity and mental well-being.

4.1. Limitations and future directions

Despite revealing the longitudinal associations between depressive symptoms and both vigorous- and moderate-intensity LTPA among first-year university students through the application of Latent Growth Modeling, this study has several limitations.

First, both the PHQ-9 (used to assess depressive symptoms) and the Godin–Shephard Leisure-Time Exercise Questionnaire (used to assess LTPA) rely on self-reported data, which may be influenced by subjective bias. Future studies could integrate objective measurement tools, such as wearable fitness trackers (e.g., heart rate and step count monitoring) and clinical interviews, to complement self-reports and more accurately capture students' LTPA engagement and psychological changes.

Second, this study tracked participants only during their first academic year, without extending to subsequent years (e.g., sophomore or junior stages). It therefore remains unclear whether the protective effects of LTPA on depressive symptoms persist beyond the transitional "freshman adaptation period." Future longitudinal research should extend the follow-up period and include additional measurement points to construct a more comprehensive developmental trajectory. Finally, although the Latent Growth Modeling approach enabled examination of the associations between the initial levels and growth rates of depressive symptoms and LTPA, potential third-variable confounding factors—such as social support, academic achievement, and sleep quality—were not incorporated into the model. Subsequent studies should control for these covariates to further clarify the causal mechanisms linking LTPA and depression trajectories.

5. Conclusions

This study focused on the first year of university—a critical transitional period for academic and personal development—to investigate the longitudinal relationships between depressive symptoms and leisure-time physical activity (LTPA) of varying intensities across one academic year. The results revealed a distinctive inverse pattern between the two trajectories: depressive symptoms started at a relatively high level and exhibited a marginally significant nonlinear decline over time, whereas LTPA began at a low level but showed a significant nonlinear increase. These trends suggest a potential synchrony between changes in physical activity and mental health during the adjustment phase of university life.

Furthermore, the association between LTPA and depressive symptoms appeared to be intensity-specific. High-intensity LTPA demonstrated a stronger protective effect against depressive symptoms at baseline, implying that the "dose" of physical activity may determine its psychological benefits. Although gender did not moderate the association between LTPA and depressive symptoms, female students displayed significantly lower baseline levels of both moderate- and high-intensity LTPA compared to males. This indicates that gender disparities in LTPA participation may arise from barriers to engagement rather than differences in psychological responsiveness to exercise.

This research provides rare longitudinal evidence highlighting the negative association between high-intensity LTPA and depressive symptoms among university students, thereby enriching the dose–response framework linking physical activity to mental health. From a practical standpoint, the findings underscore the importance of developing phase-specific, intensity-tailored, and gender-sensitive interventions in higher education. Given the high accessibility and low cost of LTPA in campus settings, integrating physical activity programs into student orientation and university mental health services could be a feasible and cost-effective approach. Such strategies may extend the reach of mental health promotion and benefit students hesitant to engage in traditional counseling. Future studies should explore the underlying mechanisms of intensity-specific effects and assess the scalability and sustainability of campus-based LTPA interventions to advance global discussions on student well-being and public health.

Declarations

Ethics approval and consent to participate

Human Ethics and Consent to Participate declarations: Ethical approval was obtained from the Institutional Review Board (IRB) of Central China Normal University (approval no. CCNU-IRB-202509002A). All procedures involving human participants were conducted in accordance with the Declaration of Helsinki. Informed consent to participate was obtained from all participants prior to data collection.

Consent for Publication

No identifiable personal data are included in this manuscript. Therefore, consent for publication is not applicable.

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Author Contribution

Conceptualization: [Xinyang Lu], Methodology: [Lingzi Yao], Formal analysis and investigation: [Lingzi Yao], Writing - original draft preparation: [Xinyang Lu]; Writing - review and editing: [Xinyang Lu, Lianghao Zhu, Lunxin Chen], Resources: [Miaomiao Wen], Supervision: [Xinyang Lu].

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