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Physical activity and subclinical depression in Chinese university students: a three-wave longitudinal study of exercise enjoyment and reward sensitivity

Fan Yi
Wuhan Vocational College of Software and Engineering
Liang Zhu
20081988z@163.com

Henan Sport University
Hailong Zhang
Zhengzhou University of Industrial Technology

Article

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Abstract

Background

Physical activity is reliably linked to lower depression, yet the affective mechanism carrying this benefit and the individual differences deciding who benefits most remain unclear. This study tested whether exercise enjoyment mediates the association between physical activity and subclinical depressive symptoms, and whether reward sensitivity moderates the path from activity to enjoyment.

Methods

A three-wave longitudinal survey followed 1,235 Chinese undergraduates across one semester, with 973 completing all waves (retention 78.8%). Physical activity and exercise enjoyment were assessed with the PARS-3 and PACES, and depressive symptoms and reward sensitivity with the CES-D and TEPS. A moderated mediation model, controlling for sex and baseline enjoyment and depression, was tested with percentile bootstrapping (5,000 resamples).

Results

T1 physical activity predicted greater T2 exercise enjoyment (a_1 = .22, p < .001), and enjoyment predicted fewer T3 depressive symptoms (b = − .28, p < .001), with a significant direct effect (c' = −.07, p = .010) indicating partial mediation. The physical activity by reward sensitivity interaction on enjoyment was significant (a_3 = .11, p < .001). The indirect effect was significant (ab = − .06, 95% CI [− .08, − .04]), as was the index of moderated mediation (a_3b = − .03, 95% CI [− .05, − .02]), and it was about three times larger among students high (− .09) than low (− .03) in reward sensitivity.

Conclusion

Exercise enjoyment is a proximal affective pathway linking physical activity to lower subclinical depression, and reward sensitivity governs its strength. Because the pathway is weakest among more anhedonic students, who may carry greater risk, physical-activity promotion may be strengthened by maximizing enjoyment and adding reward-focused components for students lower in reward sensitivity.

1 Introduction

Depression is among the leading contributors to the global burden of disease, and it commonly first emerges during late adolescence and early adulthood, which makes university students a critical population for prevention (Auerbach et al., 2018). Across countries, a substantial minority of students report clinically relevant depressive symptoms (Auerbach et al., 2018; Li et al., 2022). In China, meta-analyses estimate the pooled prevalence of depression among university students at roughly 24% to 29%, and more recent syntheses indicate that the burden has risen further, particularly since the COVID-19 pandemic (Gao et al., 2020; Lei et al., 2016; Wang et al., 2023). Because most affected students fall below diagnostic thresholds yet still experience meaningful distress and functional impairment, the identification of modifiable protective factors that can be strengthened in everyday life has become a public-health priority (Herbert, 2022; Pascoe et al., 2020).

The university years bring together academic pressure and interpersonal change at a time of growing independence, and these accumulated demands can heighten vulnerability to depressive symptoms (Li et al., 2022; Wang et al., 2023). Against this backdrop, physical activity has attracted particular attention as an inexpensive behavioral resource that can be sustained within ordinary campus life (Herbert, 2022; Pascoe et al., 2020). In contrast to specialized clinical services, exercise is broadly accessible and carries few adverse effects, which makes it well suited to population-level, preventive mental-health promotion in higher education (Chekroud et al., 2018; Huang et al., 2024).

A large evidence base now links physical activity to lower depression. Meta-analyses and umbrella reviews consistently report antidepressant effects of small-to-moderate magnitude across clinical and non-clinical populations (Noetel et al., 2024; Rebar et al., 2015; Schuch et al., 2018; Singh et al., 2023), including among students and young people (Luo et al., 2022; Men et al., 2026; Song et al., 2025). Two problems nevertheless make this evidence insufficient for guiding student mental-health promotion. The first is behavioral. Physical inactivity has risen sharply among university students under conditions of prolonged sedentary study and heavy screen use, which widens the gap between what is known to help and what students actually do (Chekroud et al., 2018; Herbert, 2022). The second is explanatory and more fundamental. The psychological mechanisms through which physical activity confers benefit, together with the individual differences that determine who benefits, remain poorly resolved (Kandola et al., 2019; Pascoe et al., 2020). In the absence of a clearer account of these mechanisms, interventions cannot be optimized or targeted, and this represents an urgent barrier given the scale and persistence of student depression (Li et al., 2022; Wang et al., 2023; Yin et al., 2025).

Efforts to explain the antidepressant effect of physical activity have largely converged on self-belief and stress-buffering resources. A rapidly growing literature, drawn in particular from studies of Chinese students, identifies resources such as exercise self-efficacy and psychological resilience, along with self-esteem and related self-belief constructs, as mediators that link activity to reduced depressive symptoms (Bandura, 2001; Chen et al., 2026; Fletcher & Sarkar, 2013; Hu et al., 2025; Huang, Chen, & Hu, 2025; Jiang et al., 2025; Latino et al., 2023; Leng et al., 2025; Li et al., 2024; Liu et al., 2024; Meng et al., 2022; Wei et al., 2024; Xiang et al., 2024; Xing & Ge, 2025; Yue et al., 2026; Zhang, 2025; Zhang, Huang, et al., 2025; Zhang et al., 2022). Although this work is valuable, it concentrates on cognitive appraisals of the self and gives little attention to the affective and reward-related processes that theories of exercise behavior and of depression treat as central. From a behavioral standpoint, the immediate affective experience of exercising, that is, the degree of pleasure or enjoyment that it generates, is a primary determinant of whether activity is repeated and sustained (Ekkekakis et al., 2011; Lee et al., 2016; Rhodes & Kates, 2015; Williams et al., 2008), and exercise enjoyment is therefore a strong candidate for the proximal mechanism through which activity improves mood (Kendzierski & DeCarlo, 1991). Depression research, in turn, identifies anhedonia, defined as a diminished capacity to anticipate and experience pleasure, as a core symptom that reflects dysregulated reward processing (Frey et al., 2023; Pizzagalli, 2014; Treadway & Zald, 2011). Reward sensitivity therefore sits on both sides of the link between exercise and depression, because it shapes how much hedonic benefit a person derives from rewarding activities and it also contributes to depressive risk (Carver & White, 1994; Gard et al., 2006). There is emerging evidence that exercise itself acts on reward and motivational systems and thereby reduces anhedonic and depressive symptoms (Kandola et al., 2019). These lines of work have not been brought together. No study has examined exercise enjoyment as the proximal affective mechanism that links physical activity to subclinical depression while also asking for whom this pathway operates, namely whether trait reward sensitivity governs the degree to which activity is translated into enjoyment. This gap is consequential, because a reward-based account predicts that students lower in consummatory reward sensitivity, and therefore with stronger anhedonic tendencies, derive less enjoyment from the same amount of activity and so experience a weaker protective pathway.

The present study addresses this gap with a three-wave longitudinal design in a sample of Chinese university students. We test a moderated mediation model in which physical activity at Time 1 predicts subclinical depressive symptoms at Time 3 through exercise enjoyment at Time 2, and in which consummatory reward sensitivity moderates the path that runs from physical activity to enjoyment. The prospective mediation analysis is complemented by a random-intercept cross-lagged panel model that distinguishes stable between-person differences from within-person change. The study first asks whether exercise enjoyment mediates the prospective association between physical activity and depressive symptoms. A second question concerns the moderating role of trait reward sensitivity in the association between physical activity and enjoyment. A third question is whether the magnitude of the indirect effect increases as reward sensitivity rises. We hypothesized that the indirect effect would be significant (H1). We further expected a positive interaction between physical activity and reward sensitivity in predicting enjoyment (H2). Finally, we predicted a significant index of moderated mediation, such that the protective indirect effect would be stronger among students higher in reward sensitivity (H3). The study locates the mechanism in an affective and reward-based process rather than in self-belief resources, and it clarifies for whom exercise is most protective, with the broader aim of informing mental-health promotion that can be targeted more precisely in higher education.

2 Method

2.1 Participants and Procedure

A three-wave longitudinal design was used, with assessments spaced approximately 10 weeks apart over one academic semester starting from September 2025 (T1 = baseline; T2 at about 10 weeks; T3 at about 20 weeks). Undergraduate students were recruited through convenience sampling from five universities in Henan Province, China; eligibility criteria were current undergraduate enrollment and provision of informed consent. The target sample size was determined a priori through a Monte Carlo power analysis for the index of moderated mediation ($a_3 \times b$), which was the least powered parameter in the model; assuming a first-stage interaction of about .10 and a b path of about − .18 with bootstrap inference, retention of approximately 1,000 participants with complete data yielded power of about .85 to .90 ($\alpha = .05$). Accordingly, 1,300 students were surveyed at baseline.

The baseline survey was administered offline in classroom settings under standardized instructions delivered by trained research staff, whereas the two follow-up surveys were administered online through a secure survey platform to facilitate retention. To link responses across waves while preserving anonymity, each participant generated a matching code from the last four digits of their mobile phone number and the last two digits of their student ID; this code was used solely for longitudinal matching and contained no directly identifying information. Attention-check items, completion-time records, and code-consistency checks were used to flag careless responding. After careless responders were excluded, 1,235 students provided valid data at T1; 1,070 completed T2, and 973 completed all three waves, for a retention rate of 78.8%. Attrition analyses indicated no significant differences between retained and dropped participants on T1 study variables. All procedures were approved by the Ethics Committee of Henan Sport University [202610220] and were conducted in accordance with the Declaration of Helsinki; all participants provided written informed consent and could withdraw at any time without penalty.

2.2 Measures

All multi-item scales used published Chinese versions. Unless noted, item scores were summed, and higher scores indicated higher levels of the construct. Internal consistency (Cronbach's α) in the present sample is reported for each scale.

Physical activity. Physical activity was assessed with the Physical Activity Rating Scale-3 (PARS-3; Liang, 1994), a three-item measure widely used with Chinese students that rates exercise intensity, duration, and frequency. The total score is computed as intensity × (duration − 1) × frequency and ranges from 0 to 100, with higher scores indicating greater physical activity participation.

Exercise enjoyment. Exercise enjoyment was measured with the 18-item Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991; Chinese version, Zhou et al., 2015). Each item is a 7-point bipolar rating of how participants feel while exercising, with higher scores reflecting greater enjoyment (α = .93).

Depressive symptoms. Subclinical depressive symptoms were assessed with the 20-item Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977; Chinese version). Participants rated how frequently they experienced each symptom during the past week on a 4-point scale (0 to 3); items 4, 8, 12, and 16 were reverse-scored. Total scores range from 0 to 60, with scores of 16 or above indicating clinically relevant symptom levels (α = .92).

Reward sensitivity. Reward sensitivity was measured with the Temporal Experience of Pleasure Scale (TEPS; Gard et al., 2006; Chinese version, Chan et al., 2012), an 18-item measure rated on a 6-point scale that yields anticipatory and consummatory subscales. In line with the hypothesized mechanism, the consummatory subscale (TEPS-CON) served as the focal moderator (α = .88 for TEPS-CON and .89 for TEPS-ANT). As a convergent index of hedonic capacity, the 14-item Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995; Chinese version, Liu et al., 2012) was also administered, with higher scores indicating greater anhedonia (α = .87).

Covariates. Participants reported sex, age, grade, only-child status, and residence (urban or rural), and they provided self-reported height and weight, which were used to compute body mass index. Baseline (T1) exercise enjoyment and depressive symptoms were included as covariates to index residualized change.

2.3 Data Analysis

Descriptive statistics, reliabilities, and bivariate correlations were computed, and within-person change across waves was examined with repeated-measures ANOVAs. The hypothesized first-stage moderated mediation model was tested in a path-analytic framework (equivalent to PROCESS Model 7): T1 physical activity predicted T2 exercise enjoyment, which in turn predicted T3 depressive symptoms, with consummatory reward sensitivity (TEPS-CON, T1) moderating the path from physical activity to enjoyment. All continuous predictors were standardized, and the models controlled for sex and for baseline (T1) exercise enjoyment and depressive symptoms [grade and body mass index were examined as additional covariates in sensitivity analyses]. The index of moderated mediation ($a_3 \times b$) and the conditional indirect effects at plus and minus one standard deviation of reward sensitivity were estimated with percentile bootstrap 95% confidence intervals (5,000 resamples), and simple-slopes analyses probed the interaction. Missing data across waves were handled with full-information maximum likelihood. As a robustness check, a three-wave random-intercept cross-lagged panel model (RI-CLPM) was estimated to separate between-person from within-person effects (Cole & Maxwell, 2003; Hamaker et al., 2015; Mulder & Hamaker, 2021). Analyses were conducted in [SPSS with the PROCESS macro / R with lavaan / Mplus].

3 Results

3.1 Preliminary Analyses

Of the 1,300 students recruited at baseline, 1,235 provided valid data at T1 after careless responders were excluded; 1,070 completed T2 and 973 completed all three waves, for a retention rate of 78.8%. Participants retained across all waves did not differ from those who dropped out after baseline on T1 depressive symptoms or the other study variables (ps > .05), which suggests that attrition was unlikely to bias the findings. Internal consistencies were acceptable to good across waves (Cronbach's α = .93 for PACES, .92 for CES-D, .88 for TEPS-CON, and .87 for SHAPS; Supplementary Table S1).

Descriptive statistics and bivariate correlations appear in Tables 1 and 2. Repeated-measures ANOVAs indicated significant change over the study period: physical activity, $F(2, 1944) = 10.49$, $p < .001$, $\eta^2p = .011$, and exercise enjoyment, $F(2, 1944) = 12.21$, $p < .001$, $\eta^2p = .012$, declined, whereas depressive symptoms increased, $F(2, 1944) = 32.89$, $p < .001$, $\eta^2p = .033$. In line with the hypothesized model, T1 physical activity was positively associated with subsequent exercise enjoyment and negatively with later depressive symptoms, exercise enjoyment was negatively associated with depressive symptoms, and consummatory reward sensitivity (TEPS-CON) was positively related to enjoyment and negatively to depressive symptoms (Table 2).

Table 1
Sample Characteristics and Study Variables Across Waves

Variable	T1 M (SD)	T2 M (SD)	T3 M (SD)	F	p	η^2p
Demographics						
Female, n (%)	717 (58.1)					
Age (years), M (SD)	20.44 (1.69)					
BMI, M (SD)	21.20 (2.87)					
Only child / Urban, %	47.6 / 55.6					
Study variables						
Physical activity (PARS-3)	21.77 (21.44)	19.90 (18.74)	19.50 (19.62)	10.49	< .001	0.011
Exercise enjoyment (PACES)	89.76 (15.16)	89.14 (15.18)	87.90 (14.94)	12.21	< .001	0.012
Depressive symptoms (CES-D)	14.62 (9.34)	15.41 (9.27)	16.13 (9.59)	32.89	< .001	0.033
Reward sensitivity, consummatory	36.96 (7.29)	(T1 only)				
Reward sensitivity, anticipatory	40.89 (8.09)	(T1 only)				
Anhedonia (SHAPS)	27.35 (6.95)	(T1 only)				

Note. n = 973 with complete three-wave data. F, p, and η^2p are from within-subjects repeated-measures ANOVA testing the effect of wave. Physical activity and exercise enjoyment declined and depressive symptoms increased over the study period (all p < .001). TEPS and SHAPS were assessed at T1 only.

Table 2
Bivariate Correlations Among Study Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Physical activity T1	1.00											
2. Physical activity T2	.32***	1.00										
3. Physical activity T3	.19***	.26***	1.00									
4. Enjoyment T1	.36***	.19***	.10**	1.00								
5. Enjoyment T2	.42***	.21***	.11***	.53***	1.00							
6. Enjoyment T3	.30***	.33***	.16***	.28***	.48***	1.00						
7. Depression T1	−.18***	−.08**	−.04	−.33***	−.28***	−.17***	1.00					
8. Depression T2	−.21***	−.09**	−.08*	−.32***	−.30***	−.15***	.53***	1.00				
9. Depression T3	−.25***	−.15***	−.04	−.34***	−.42***	−.27***	.53***	.51***	1.00			
10. Reward, consummatory	.15***	.13***	.08*	.17***	.24***	.15***	−.20***	−.18***	−.17***	1.00		
11. Reward, anticipatory	.06*	.07*	.02	.09**	.12***	.07*	−.09**	−.06	−.09**	.44***	1.00	
12. Anhedonia	−.12***	−.07*	−.01	−.12***	−.11***	−.08*	.10***	.08*	.10**	−.51***	−.22***	1.00

*Note. pairwise N up to 1,235. Reward, consummatory and Reward, anticipatory denote the TEPS-CON and TEPS-ANT subscales; higher anhedonia (SHAPS) denotes lower pleasure capacity. * p < .05. ** p < .01. *** p < .001.*

3.2 Test of the Moderated Mediation Model

The hypothesized first-stage moderated mediation model was tested in a path-analytic framework, controlling for sex and for baseline (T1) exercise enjoyment and depressive symptoms; all continuous predictors were standardized (Table 3; Fig. 1). As predicted, T1 physical activity positively predicted T2 exercise enjoyment (a_1 = .22, p < .001), and T2 enjoyment negatively predicted T3 depressive symptoms (b = − .28, p < .001). The direct effect of physical activity on depressive symptoms remained significant (c' = −.07, p = .010), which indicates partial mediation.

Of central interest, the interaction between physical activity and reward sensitivity in predicting enjoyment was significant (a_3 = .11, p < .001), supporting the hypothesis that consummatory reward sensitivity moderates the a path. Simple-slopes analysis (Fig. 2) showed that the association between physical activity and enjoyment was stronger among students high in reward sensitivity (+ 1 SD; simple slope = .33, p < .001) than among those low in reward sensitivity (− 1 SD; simple slope = .11, p = .007), and both slopes were positive and significant.

Table 3
Regression Coefficients for the Longitudinal Moderated Mediation Model

Predictor	β	SE	t	p
Mediator model: DV = Exercise enjoyment (T2)				
Physical activity T1 (a_1)	.22	0.028	+ 7.94	< .001
Reward sensitivity, TEPS-CON (a_2)	.12	0.027	+ 4.40	< .001
PA × Reward (a_3)	.11	0.026	+ 4.22	< .001
Baseline enjoyment (T1)	.39	0.029	+ 13.34	< .001
Sex	.08	0.052	+ 1.61	0.108
Baseline depression (T1)	−.08	0.028	-2.80	0.005
R^2 = 0.359				
Outcome model: DV = Depressive symptoms (T3)				
Exercise enjoyment T2 (b)	−.28	0.029	-9.86	< .001
Physical activity T1 (c')	−.07	0.028	-2.58	0.010
Baseline depression (T1)	.44	0.026	+ 16.82	< .001
Sex	.10	0.052	+ 1.92	0.055
R^2 = 0.373				

3.3 Indirect and Conditional Indirect Effects

Percentile bootstrap analyses (5,000 resamples) appear in Table 4. The overall indirect effect of physical activity on depressive symptoms through exercise enjoyment was significant (ab = − .06, 95% CI [− .08, − .04]). The index of moderated mediation was significant (a_3b = − .031, 95% CI [− .05, − .02]), which indicates that the strength of the indirect effect depended on reward sensitivity. The protective indirect effect was about three times larger among students high in reward sensitivity (+ 1 SD; −.09, 95% CI [− .12, − .07]) than among those low in reward sensitivity (− 1 SD; −.03, 95% CI [− .05, − .01]), and both confidence intervals excluded zero.

Table 4
Total, Direct, Indirect, and Conditional Indirect Effects

Effect	Estimate	95% CI (bootstrap)
Total effect (X to Y)	−.18	
Direct effect (c')	−.07	
Indirect effect (a × b, at mean reward)	−.06	[− .08, − .04]
Index of moderated mediation (a_3 × b)	**−.03**	**[− .05, − .02]**
Conditional indirect: −1 SD reward	−.03	[− .05, − .01]
Conditional indirect: +1 SD reward	−.09	[− .12, − .07]

4 Discussion

This study examined whether exercise enjoyment operates as an affective mechanism that links physical activity to subclinical depressive symptoms in Chinese university students, and whether consummatory reward sensitivity determines the strength of that mechanism. Using a three-wave longitudinal design and a moderated mediation model, we found support for each of the three hypotheses. Physical activity predicted later depressive symptoms indirectly through exercise enjoyment, the strength of the path from activity to enjoyment depended on reward sensitivity, and the protective indirect effect was larger among students with greater reward sensitivity. Together, the findings point to an affective and reward-based account of how, and for whom, physical activity is associated with student mental health.

Consistent with the first hypothesis (H1), exercise enjoyment mediated the prospective association between physical activity and depressive symptoms. Students who were more physically active at baseline reported greater enjoyment of exercise at the second wave, and greater enjoyment in turn predicted fewer depressive symptoms at the third wave. This result fits behavioral accounts in which the immediate affective quality of exercise governs whether activity is repeated and whether it yields psychological benefit (Ekkekakis et al., 2011; Lee et al., 2016; Rhodes & Kates, 2015; Williams et al., 2008). It also extends the mechanism literature on physical activity and student mental health, which has concentrated on self-belief resources such as self-efficacy and resilience (Liu et al., 2024; Wei et al., 2024; Yue et al., 2026), by showing that a hedonic pathway contributes beyond these cognitive appraisals. Because the direct effect of physical activity remained significant, enjoyment accounted for part but not all of the association, which indicates that additional physiological and psychosocial routes are likely to operate in parallel (Kandola et al., 2019).

Consistent with the second hypothesis (H2), the association between physical activity and exercise enjoyment was moderated by consummatory reward sensitivity. Simple-slopes analysis showed that the same amount of activity translated into more enjoyment for students high in reward sensitivity than for students low in reward sensitivity. This pattern aligns with reward-processing models of pleasure, in which the capacity to experience reward shapes the hedonic value that a person derives from potentially rewarding behavior (Carver & White, 1994; Gard et al., 2006; Pizzagalli, 2014; Treadway & Zald, 2011). The finding also connects the exercise-behavior literature to the depression literature, because reduced consummatory capacity is a defining feature of anhedonia and a core component of depressive risk (Frey et al., 2023). By identifying an individual difference that governs how much enjoyment activity produces, the result begins to specify for whom exercise is affectively rewarding.

Consistent with the third hypothesis (H3), the index of moderated mediation was significant, and the conditional indirect effect was stronger at higher levels of reward sensitivity. The protective pathway that runs from physical activity through enjoyment to lower depressive symptoms was amplified among students with greater reward sensitivity and attenuated among those with more anhedonic tendencies. This finding carries a notable implication. Students whose reward capacity is already reduced, and who may therefore be at elevated risk for depression, appear to gain less benefit from the enjoyment route of ordinary exercise promotion. In other words, the pathway that helps most tends to work least well where vulnerability is greatest, which suggests that a general encouragement to be active may be insufficient for the students who most need support (Kandola et al., 2019; Pizzagalli, 2014).

Theoretically, the results reposition the mechanistic account of exercise and student mental health. Rather than treating the benefit of activity as a product of strengthened self-belief, the present findings locate a proximal mechanism in the affective experience of exercising and in the reward system that gives that experience its value. This integration links two literatures that have developed largely in isolation, namely the study of affective responses to exercise and the study of reward dysfunction in depression (Ekkekakis et al., 2011; Pizzagalli, 2014). Reward sensitivity emerges not only as a correlate of depression but as a moderator that conditions the psychological return on physical activity.

The findings also have practical value for mental-health promotion in higher education. Because enjoyment carried the protective effect, exercise promotion may be strengthened by prescribing activity in ways that maximize in-the-moment pleasure, for example by allowing students to self-select intensity and modality (Ekkekakis et al., 2011). In addition, because the enjoyment route was weaker for students lower in reward sensitivity, universal promotion may need to be supplemented for this subgroup with strategies that directly target reward and positive affect, such as behavioral activation and savoring-based approaches (Craske et al., 2016; Dimidjian et al., 2011). Promotion that is tailored to reward sensitivity may therefore be more effective than a uniform message to be active.

4.1 Limitations and Future Directions

Several limitations qualify these conclusions. Although the three-wave design established temporal ordering, the study remained observational, so causal claims are not warranted; reciprocal processes are plausible, including effects of enjoyment on subsequent activity and of depressive symptoms on later engagement. The reliance on self-report across all constructs raises the possibility of common-method variance. A further concern is timescale, because exercise enjoyment was assessed at the level of survey waves rather than during activity itself, yet the affective benefit of exercise unfolds over minutes to hours, so ecological momentary assessment would capture the mechanism more directly. Reward sensitivity was indexed by a self-report scale, and behavioral or neural measures would permit stronger inference about the reward system. Generalization is also constrained, because the sample comprised Chinese university students recruited by convenience.

Future research can address these issues by combining ecological momentary assessment of in-activity affect with behavioral or neural indices of reward, and by testing, in a randomized design, whether interventions that enhance exercise enjoyment reduce depressive symptoms and whether the addition of reward-focused components improves outcomes for students low in reward sensitivity.

4.2 Conclusion

In conclusion, physical activity was prospectively associated with lower subclinical depressive symptoms in part because it generated exercise enjoyment, and this affective pathway was stronger for students with greater consummatory reward sensitivity. The findings support an affective and reward-based mechanism and identify reward sensitivity as a marker of who benefits most, which offers a basis for more precisely targeted physical-activity promotion in student mental health.

Declarations

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of Henan Sport University and was performed in line with the Declaration of Helsinki. The ethical approval number is 202610220. Informed written consent was obtained from all individual participants included in the study.

Clinical trial number

Not applicable. Participants were individuals with self-reported depressive and anxiety symptoms recruited from a non-clinical population, without formal clinical diagnoses, and the intervention was rather than a medical or health-care intervention evaluating a biomedical or health-related outcome.

Data Availability

Data will be available upon request.

Competing Interests

The authors declare that they have no conflicts of interest.

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Figures

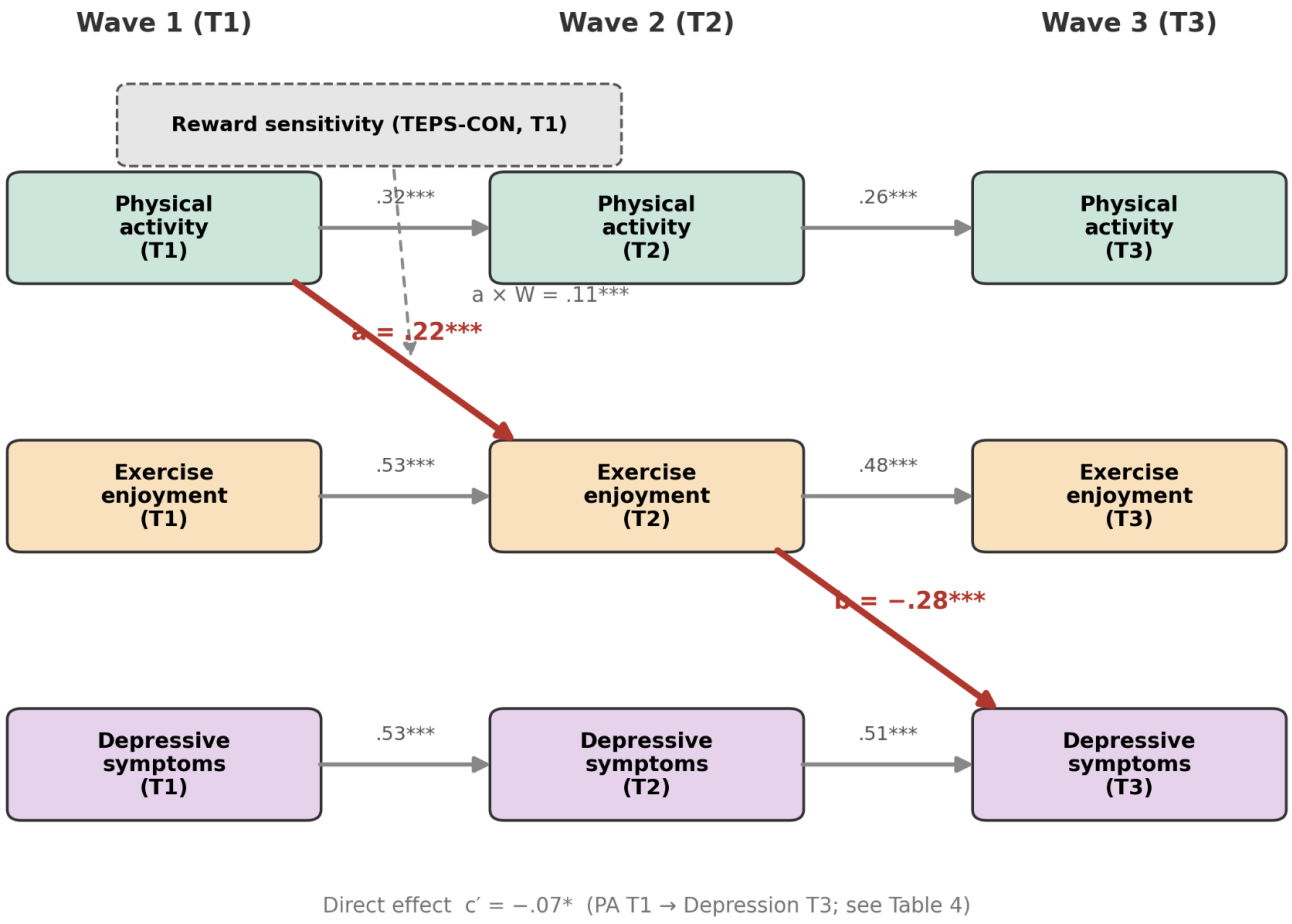


Figure 1

Three-wave longitudinal moderated mediation model. Each construct was assessed at all three waves; horizontal grey paths are autoregressive stabilities, and the bold red path is the focal indirect chain (physical activity T1 to exercise enjoyment T2 to depressive symptoms T3). Reward sensitivity (TEPS-CON) moderates the a path; the direct effect is reported in Table 4. *** p < .001, * p < .05.

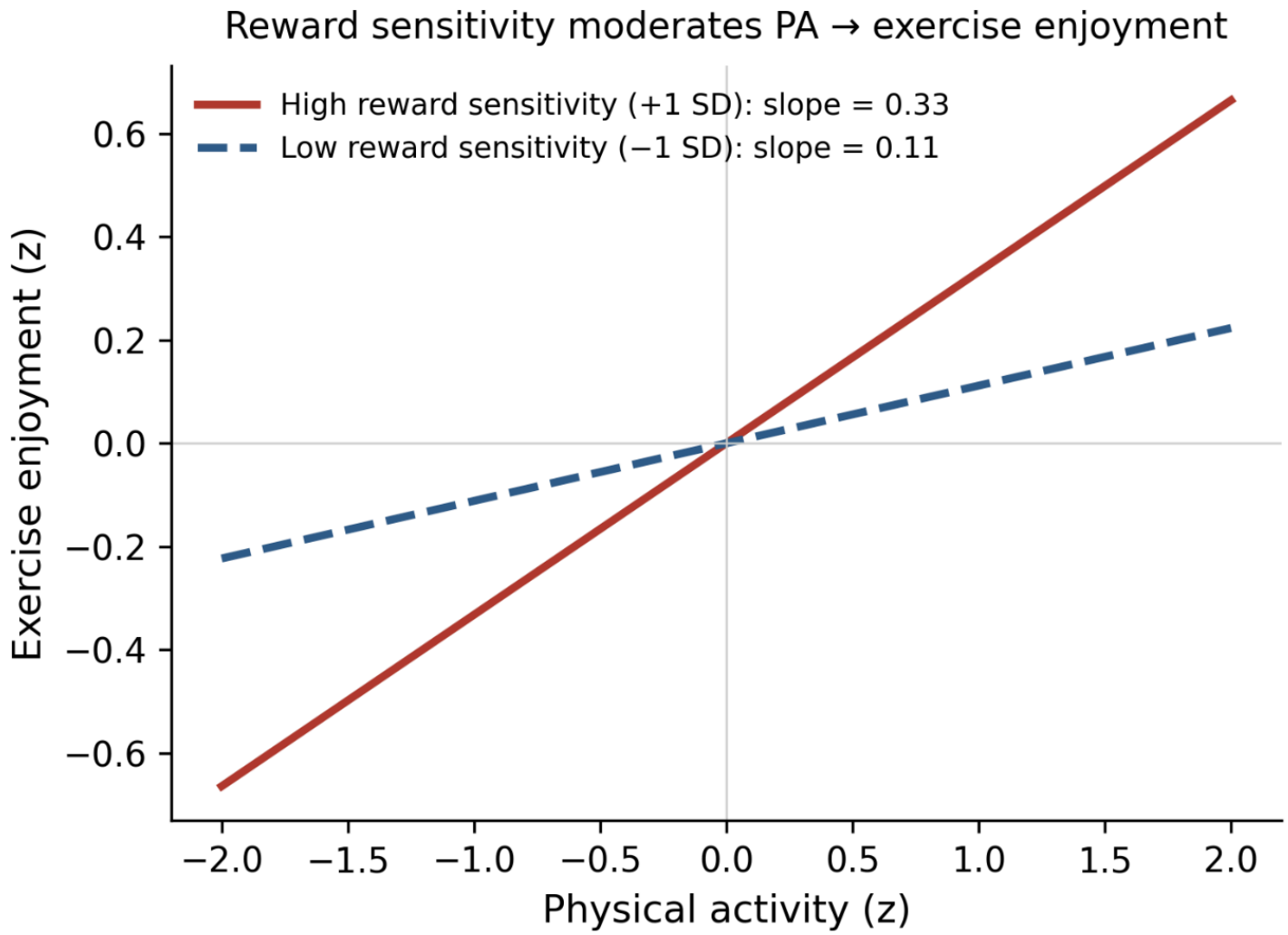


Figure 2

Simple slopes of the physical activity to exercise enjoyment (a) path at high versus low reward sensitivity.