International Journal of Clinical and Health Psychology 22 (2022) 100312

International Journal of Clinical and Health Psychology

www.elsevier.es/ijchp

ORIGINAL ARTICLE

The roles of exercise tolerance and resilience in the effect of physical activity on emotional states among college students

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Received 16 March 2022; accepted 24 March 2022
Available online xxx

KEYWORDS
Exercise tolerance;
Resilience;
Physical activity;
Emotion;
Depression

Abstract
Background/objective: Negative emotional states, such as depression, anxiety, and stress challenge health care due to their long-term consequences for mental disorders. Accumulating evidence indicates that regular physical activity (PA) can positively influence negative emotional states. Among possible candidates, resilience and exercise tolerance in particular have the potential to partly explain the positive effects of PA on negative emotional states. Thus, the aim of this study was to investigate the association between PA and negative emotional states, and further determine the mediating effects of exercise tolerance and resilience in such a relationship. *Method:* In total, 1117 Chinese college students (50.4% female, M_{age}=18.90, *SD*=1.25) completed a psychosocial battery, including the 21-item Depression Anxiety Stress Scale (DASS-21), the Connor-Davidson Resilience Scale (CD-RISC), the Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q), and the International Physical Activity Questionnaire short form (IPAQ-SF). Regression analysis was used to identify the serial multiple mediation, controlling for gender, age and BMI. *Results:* PA, exercise intensity-tolerance, and resilience were significantly negatively correlated with negative emotional states (Ps$<$.05). Further, exercise tolerance and resilience partially mediated the relationship between PA and negative emotional states. *Conclusions:* Resilience and exercise intensity-tolerance can be achieved through

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https://doi.org/10.1016/j.ijchp.2022.100312

regularly engaging in PA, and these newly observed variables play critical roles in prevention of mental illnesses, especially college students who face various challenges. Recommended amount of PA should be incorporated into curriculum or sport clubs within a campus environment.

Introduction

College students undergo a critical developmental transition from adolescence to adulthood. Although these emerging adults strive to achieve high levels of intellect, ambition, and self-esteem (Pedrelli et al., 2015), they still have to face typical challenges for this developmental stage, such as finding an accommodation, engaging in relationships, coping with competitive and academic difficulties, financial stress, and struggling to make important decisions (Parker et al., 2004). Consequently, a considerable number of college students develop stress-related mental disorders (e.g., depression and anxiety), which limit their daily activities and academic performance (Fam, 2018; Sobocki et al., 2006). Specifically, stress, anxiety, and depression are typically elicited in individuals (including college students) when faced with an unpredictable or challenging situation or event (Ketata et al., 2021). Additionally, individuals have reported feeling emotionally worse during the COVID-19 pandemic as compared to how they felt pre-pandemic (Chi et al., 2020; Chi et al., 2022; Chi, Liang, et al., 2021; Hossain et al., 2020). For instance, during the COVID-19 pandemic the prevalence of stress, anxiety, and depression in the global general population reached 29.6%, 31.9%, and 33.7%, respectively (Salari et al., 2020). Furthermore, college students in emerging adulthood are more likely to present these emotional states because they have difficulty adjusting during this developmental transition period (Arnett & Tanner, 2006); this may be exacerbated during the COVID-19 pandemic (Wang et al., 2020). A recent meta-analysis investigating the psychological effects of COVID-19 suggests a relatively high prevalence of stress (23%), anxiety (29%), depression (37%) among college students (Wang et al., 2021). Thus, searching for protective factors in this particular cohort of emerging adults is urgently needed, which allows for a timely implementation of interventions to effectively alleviate negative emotions as the current strategies and vaccines cannot fully protect against the globally continuous COVID-19 pandemic.

One of the most frequently studied protective factors against stress, anxiety, and depression is physical activity (PA) (Anderson & Shivakumar, 2013; Chi, Liang, et al., 2021; Moljord et al., 2014). PA is defined as a type of bodily movement that consumes energy from skeletal muscles and (US Department of Health & Human Services, 1996) has beneficial psychological effects (Miles, 2007). Specifically, the positive links of PA with stress, anxiety, and depression have been well documented across different age groups and individuals with or without chronic illnesses (Dinas et al., 2011; Kandola et al., 2019; Rethorst et al., 2009; ter Riet et al., 2012). Such psychological benefits from regular engagement in PA can be attributed to changes occurring at different levels of analysis: (i) molecular level; (ii) brain structure and function; and, (iii) psycho-social factors (Stillman et al., 2020). From a molecular perspective, brain-derived neurotrophic factor (BDNF) which is the most abundant neurotrophic factor in the brain, has been shown to be associated with PA level (Huang et al., 2014). There is evidence to suggest that decreased BDNF levels, especially in the hippocampus, are correlated with stress-induced depression and anxiety (Altar, 1999; Duman & Monteggia, 2006). In terms of brain structure and function, the exercise-induced changes in the hypothalamic-pituitary-adrenal (HPA) axis are observed to play a critical role in the manifestations of depression and anxiety symptoms (Anderson & Shivakumar, 2013). With respect to psychological factors, researchers have recently paid great attention to resilience and have proposed that PA reduces negative emotion through improved resilience (Moljord et al., 2014).

While there are many different definitions for psychological resilience (Sisto et al., 2019), the fundamental concept is the ability to maintain or regain mental health despite adverse conditions (Afek et al., 2021). Resilience especially comes into play in dealing with and tolerating challenging or troublesome situations, such as stress, anxiety, and depression. Empirical studies have documented that resilience is negatively correlated with the aforementioned emotional states, and it can maintain or even improve the mental health of college students (Hartley, 2011). Therefore, exploring how to build resilience may help individuals suffering from negative emotional states, such as depression and anxiety. In addition, cardiorespiratory fitness, whether achieved through regular PA and/or structured physical exercise program, can promote resilience (Li et al., 2020). In this context, the following pathways might mediate the positive effect of PA and/or physical fitness on resilience-related parameters: (i) stress-buffering effects on negative emotions, (ii) elevating neurophysiological adaptations to external stressors, (iii) enhancing an anti-inflammatory state, and (iv) increasing neuroplasticity and growth factor expression (Silverman & Deuster, 2014). Specifically, researchers have hypothesized that PA, especially physical exercise as structured, planned, and repetitive form of PA, serves as an sporadic stressor on the physical body that can maximize adaptation to other types of stressors (e.g., psychological stressors) (Budde et al., 2016; Caspersen et al., 1985). In terms of the biological profile, physiological toughening refers to an initially elevated catecholamine response, followed by a quick recovery and decreased HPA axis responses (similar to the mechanism of PA in improving depression and anxiety). Such physiological changes were observed to associate with enhanced performance during challenging/stressful situations, increased tolerance to stressors (e.g., improved resilience), and increased emotional stability (e.g., reduced anxiety and depression). Collectively, PA may help individuals neurophysiological adapt to external stressors and ultimately reduce stress-induced anxiety and depression (Sothmann et al., 1996). Taken

together, relatively high levels of regular PA are positively associated with mental health among adolescents (Chi, Liang, et al., 2021). Therefore, resilience, among other factors, may be presumably an important mediator between PA and negative emotional states especially in individuals being at risk of developing mental disorders (Hegberg & Tone, 2015).

To better understand the association between PA and negative emotional states, researchers incorporated "affective responses to exercise" into current theoretical models of exercise behavior (Ekkekakis et al., 2005b, 2008; Stych & Parfitt, 2011). Exercise tolerance is defined as an ability to continuously perform exercise plans despite exercise intensity beyond the physiological threshold even when the activity is experienced as unpleasant/uncomfortable (Ekkekakis et al., 2005a). According to a previous study, exercise tolerance is positively associated with vigorous leisure-time PA (Teixeira et al., 2021). Furthermore, there is some overlap in the definition of exercise tolerance and psychological resilience. Both of them involve persistence and adaptation in difficult situations, but exercise tolerance is related to high exercise intensity and psychological resilience is related to real dilemmas. Despite the lack of research on exercise tolerance and resilience, a few studies have revealed a potential association between these two factors. As Ekkekakis et al. (2007) found in a response to a circuit training, the exercise-induced hypoalgesia (resulting in tolerance to high exercise intensity) was achieved through changes in pain tolerance levels, which seems to be comparable to the mechanism of PA to improve resilience.

The current evidence provides some indications that PA, exercise tolerance, resilience and negative emotional states are related in a way; that increased exercise can lead to higher levels of exercise tolerance and resilience thereby reducing negative emotional states. Therefore, the present study aimed to investigate the serial multiple mediating effects of exercise tolerance and resilience between PA level and negative emotional states in a cohort of Chinese college students. In this study we hypothesized that PA improves individuals' ability to persist and adapt themselves in uncomfortable activity situations, which can be transferred to troublesome situations in daily life (i.e., psychological resilience). In other words, PA can improve psychological resilience, with exercise tolerance as a mediating factor. Further, we want to investigate whether the effects of PA level on depression and anxiety were mediated by the psychological factors operationalized via exercise tolerance and resilience. Specifically, we hypothesized that: (1) PA level would be negatively correlated with stress, anxiety, and depressive symptoms, and (2) exercise tolerance and psychological resilience mediate the association between PA level and negative emotional states.

Methods

Participants

A snowball sampling (Goodman, 1961) was used to reach the targeted population of college students aged between 18 and 25. In particular, researchers contacted their collaborators who were faculty members from different universities across China and informed them about this study and asked for their help with data collection. Those faculty members had distributed the pre-designed QR code to their students and asked them to voluntarily participate in this study. Of note, all participants were informed about the aim of this study and required to complete an e-signature for their informed consent prior to starting the questions about their demographic data and other subsequent procedures. A total of 1245 Chinese college students volunteered to attend this study, but valid responses were obtained from 1117 participants (563 women, 554 men, M = 18.90, SD = 1.25) after removing those participants who responded with an unacceptable short duration (researchers had several tests and were informed about how long the survey should last) and did not pass the lie detector quiz. This study protocol (PN-2020-041) was approved by the ethical committee of Shenzhen University before data collection. Of note, the present study was a part of a project entitled "Validation Study on PRETIE-Q and its associations with physical and psychological mental health".

Measures

The 21-item Chinese version of Depression Anxiety Stress Scale (DASS-21) was used to assess the magnitude of three negative emotional states: depression, anxiety, and stress (Lovibond & Lovibond, 1996; Taouk et al., 2001). It includes 21 items, with each rated on a 4-point scale (0—3). Scores for three separate subdomains and total scores for this questionnaire were calculated, with higher scores reflecting greater level of negative emotional states. Cronbach's alpha of this questionnaire in the present study was 0.94.

The Chinese version of Connor-Davidson resilience scale (CD-RISC) was used to measure resilience over the past one month (Connor & Davidson, 2003; Yu & Zhang, 2007). This questionnaire consists of 25 items, with each response on a 5-point scale: Zero (not true at all) to four (true nearly all of the time). Cronbach's alpha of the CD-RISC in the present study was 0.94.

Exercise intensity-tolerance and preference were measured using a Chinese version (under review) of the Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q; Ekkekalis et al., 2005), which is a 8-item self-administered instrument in the present study. Each item was rated on a 5-point Likert scale ranging from 1 (I totally disagree) to 5 (I totally agree). Scores for two different domains (tolerance and preference) were separately computed: 1) with higher scores indicating greater tolerance for exercise intensity; 2) with higher scores indicating greater preference for low exercise intensity. Cronbach's α of the PRETIE in the present study was 0.85 (preference) and 0.72 (tolerance). Of note, only exercise intensity-tolerance was used for data analysis in the present study.

PA level was measured using the Chinese version (Qu & Li, 2004) of the short form of the International PA Questionnaire (IPAQ-SF; Craig et al., 2003). The IPAQ-SF includes 7 items assessing four different movement behaviors over the past week: vigorous-intensity activity, moderate-intensity activity, light-intensity walking, and sitting behavior. Total PA level (reflected by metabolic equivalent, MET) was calculated by summing time spent in walking and in moderate-to-vigorous PA, in accordance with the scoring protocol.

Macfarlane et al. (2007) reported that the Chinese version of IPAQ-SF has the test-retest reliability coefficients of 0.93 for mild, 0.85 for moderate, and 0.75 for vigorous exercise.

Maximal oxygen uptake (VO_{2max}) was measured as an indicator of cardiorespiratory fitness using a bicycle ergometer (Ergoselect 200 K). After a two-minute warm-up phase, participants were instructed to maintain stable pedal rotations (ranging from 55 to 60 per minute) regardless of a gradual elevation of 20 W per minute (i.e., starting workload: 0 W, incremental workload: 20 W, additional charge: 1 min by 20 W, cadence: 55−60 rpm). The test was terminated when the rotation rate was lower than 50 r/min, the heart rate greater than 180 beats/min, respiratory quotient (RQ) > 1.10, or a plateau of the predicted VO_{2max}.

Statistical analysis

Data were analyzed with SPSS 21.0 and PROCESS (Hayes, 2017). Specifically, a widely used macro program for SPSS to analyze mediation and moderation models. First, descriptive analysis, including the calculation of means and standard deviation (SD), were conducted (see **Table 1**). In the second step, Pearson correlations between each two dependent variables (PA level, resilience, exercise intensity-tolerance, and negative emotional states) were determined and categorized as follows: 0 to 0.19: no correlation; 0.2 to 0.39: low correlation, 0.40 to 0.59: moderate correlation; 0.60 to 0.79: moderately high correlation; ≥ 0.80: high correlation (Zhu, 2012, 2016). Of note, significant correlations were further investigated while controlling for several covariables including sex, age and BMI. In the third step, the mediation analyses were performed using model 6 of the PROCESS macro, to better understand whether and how the negative association between PA level and negative emotional states were mediated by exercise tolerance and resilience. Specifically, the regression analysis was used to identify the serial multiple mediation standardized effects of resilience and tolerance between PA level and DASS total score. As the VO2max was collected in Study 2, but with a relatively small number of participants on this variable, only bivariate correlation analysis was conducted. In accordance with the literature, the mediation effects are considered as significant when the 95% bias-corrected bootstrap confidence intervals do not include zero (Hayes, 2009; Hayes & Rockwood, 2017). A p-value of 0.05 was considered statistically significant when a two-tailed test was used.

Results

Participant characteristics

Results of descriptive statistics and gender variance analyses for all main study variables are presented in **Table 1**. The final sample comprised 1117 participants. A significant gender difference on body mass index (BMI, calculated by dividing weight [kg] by height [m^2]) was observed. Additionally, male participants demonstrated significantly higher age, greater resilience and exercise intensity-tolerance as compared with female counterparts, yet with a non-significant difference on PA level.

Correlations of all tested variables

The magnitude of correlations between each two variables ranged from no correlation to moderate level (r = -0.03 to 0.53). IPAQ-SF, CD-RISC and PRETIE are significantly positively related to each other, whereas these variables are significantly negatively related to DASS. As shown in **Table 2**, exercise tolerance is not significantly related to negative emotional states.

Multiple mediation model

As shown in **Table 3** and **Fig. 1**, results indicated that the 95% CI for the total, direct and indirect effects did not include zero. After controlling for the covariates (gender, age and BMI), results indicated that the total and direct effect of PA level on negative emotional states were statistically significant. Examination of indirect effects showed that exercise tolerance and resilience reached statistical significance as mediators of the PA-DASS relationship. There were three indirect effects statistically significant based on the regression analysis: PA → exercise tolerance → resilience → negative emotional states; PA → exercise tolerance → negative emotional states; and PA → resilience → negative emotional states.

CRF (cardiorespiratory fitness)-related associations

In the present study, CRF is significantly associated with exercise intensity-tolerance, with a positive direction (r = 0.499, p <.01), while resilience is significantly associated with negative emotional states (r = -0.335, $p < .05$)

Table 1 Gender difference on sociodemographic and anthropometric.

Variables	Total (1117)	Male (554)	Female (563)		
	M ±SD	M ±SD	M ±SD	T	p
Age(years)	18.90 ±1.25	19.03 ±1.26	18.78 ±1.217	3.43**	0.001
BMI (kg/$m^{2)}$	20.94 ±3.05	21.76 ±3.33	20.12 ±2.50	9.30**	0.000
PA level (MET)	2590.51 ±1192.41	2593.53 ±1190.24	2587.53 ±1195.59	0.08	0.933
Exercise Tolerance	12.82 ±2.70	13.25 ±2.73	12.40 ±2.60	4.79**	0.000
Resilience	87.83 ±14.3	89.88 ±15.05	85.82 ±13.25	5.33**	0.000
DASS (total score)	35.07±10.60	35.93 ±11.20	34.22 ±9.91	2.70*	0.007

Note. MET = metabolic equipment, DASS = Depression Anxiety Stress Scale, PA = physical activity,
* $p < .01$.
** $p < .001$.

Table 2 Correlations of all tested variables.

Variables	PA level	Exercise Tolerance	Resilience	DASS (Total score)
PA level (MET)				
Exercise Tolerance	0.099**			
Resilience	0.098**	0.247**		
DASS (total score)	-0.087**	-0.005	-0.304**	

Note. DASS: Depression Anxiety Stress Scale, PA = physical activity.
** $p < .01$.

Table 3 Mediation modeling results.

Path	Standardized Effect	SE	LLCI	ULCI
Total effect	-0.087057	0.000265	-0.003528	-0.000255
Direct effect	-0.061435	0.000253	-0.001043	-0.000050
Total indirect effects	-0.025622	0.000097	-0.000422	-0.000046
Indirect 1	0.006714	0.000060	0.000032	0.000128
Indirect 2	-0.024934	0.000092	-0.000406	-0.000048
Indirect 3	-0.007402	0.000025	-0.0001214	-0.000024

Note. SE, standard error; LLCI and ULCI, lower level and upper level of the bias-corrected 95% bootstrap confidence interval; Indirect 1, PA level → exercise tolerance → DASS; Indirect 2, PA level → resilience → DASS; Indirect 3, PA level → exercise tolerance → resilience → DASS.

Discussion

This study aimed to gain a better understanding regarding the possible associations between PA level and emotional states, and the potential role of exercise tolerance and resilience as mediators of such a relationship. Firstly, our findings reveal a significant and negative association between PA level and emotional states. This finding is consistent with previous studies and supported the positive effect of a relatively high PA level on emotional states (Anderson & Shivakumar, 2013; Dinas et al., 2011; Kruk et al., 2019; Teixeira et al., 2013). More importantly, the promising results of the present study helped to explain how PA results in reductions of negative emotional states (stress, anxiety, and depression), mainly due to the serial mediation effects of exercise tolerance and resilience. These results are discussed below.

The psychological mechanisms of PA-induced effects on negative emotions have been examined in recent decades. Of note, results of the present study showed that associations of resilience with PA and negative emotional states (stress, anxiety, and depression). Specifically, resilience was positively associated with PA level and negatively with stress-related negative emotions, although the correlation coefficient for the former is relatively low. Rutter (1985) suggested that psychological resilience protects individuals against challenging situations primarily through four potential pathways: (a) decreasing risk impact; (b) minimizing negative chain reactions; (c) building up psychological abilities like stronger self-esteem and self-efficacy; and (d) creating opportunities for adaptive responses. There are some studies available that explored the association between resilience and these two variables (PA level and negative emotional states) and have obtained similar results to the present study (Moljord et al., 2014; Stych & Parfitt, 2011). Simultaneously, some studies addressed that exercise activates physical responses in order to enhance resilience, which could indirectly reduce the negative impact of stress on negative emotions through its mediating effect (Anyan & Hjemdal, 2016; Ma et al., 2019). In other words, resilience represents a dynamic process. While being physically active, the individual exerts a top-down regulation, so as to achieve the internal balance (internal steady state), which, in turn, attenuates the negative emotions caused by the

Table 4 Associations of VO2max with resilience, intensity-tolerance, and emotional states.

	VO_{2max}	Exercise tolerance	Resilience	DASS
VO_{2max}				
Exercise tolerance	0.499**			
Resilience	0.177	0.239		
DASS	-0.091	-0.226	-0.335*	

Note.
* $p < .05$.
** $p < .01$, DASS=Depression Anxiety Stress Scale, VO_{2max} = maximal oxygen uptake.

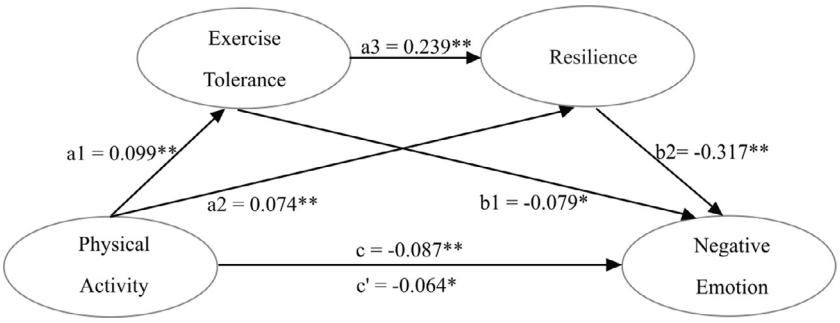

Figure 1 Conceptual and statistical diagram of the multiple mediation model for the direct and indirect effects of PA on negative emotions. *$p < .05$; **$p < .01$.

physiological reaction originating by being physical active (Belcher et al., 2021). Therefore, resilience is likely to play an important role in exercise to relieve negative emotions.

The current study also found that the exercise tolerance related to resilience was another significant mediator of the association between PA level and emotional states, extending previous findings about this relationship. Resilience did not independently mediate the association between PA level and emotional states, which indicated that exercise tolerance may play a more important role in the link between regular PA and emotional states. Specifically, college students with a higher PA level also show a higher level of exercise tolerance, which, in turn, led to less stress, anxiety, and depression. However, previous studies on exercise tolerance have mainly focused on patient populations in order to explore ways to improve exercise tolerance. For example, Burtscher et al. (2010) found that the beneficial effects of interval hypoxia training on exercise tolerance seem to be greater in patients with coronary artery disease or chronic obstructive pulmonary disease when compared to healthy participants, as higher exercise tolerance is associated with lower mortality. Similarly, another study provided evidence that spinal anesthesia enhances exercise tolerance in patients with chronic obstructive pulmonary disease (Gagnon et al., 2012). Although there is no study focusing on the relationship between exercise tolerance and emotional states, and it has been suggested that regular exercise can improve exercise tolerance (Ferguson et al., 2007). In this context, this is a new idea that increasing PA levels, which increases exercise tolerance and ultimately reduces stress, anxiety and depression.

Lastly, our finding supports our hypothesis that PA exerts an influence on emotional states among college students is mediated by exercise tolerance and resilience. In particular, the path was PA → exercise tolerance → resilience → emotional states. We hold the opinion that usually when performing some high intensity exercise, when the force is exhausted, individuals need to keep persevering, which is like facing a setback, and in such a process hones their will, thereby developing their resilience. Such resilient students tend to perceive the challenging and unpleasant conditions as non-permanent, and thus strengthen defenses against negative emotions about the pandemic, and experience positive emotions. From a practical perspective, university administrators should create a physically active environment by increasing the accessibility of sports facilities and incorporating exercise sessions (recommended by ACSM) into a curriculum, which could help students get into the habit of exercise for improving mental health. The results of this study provide a new perspective for the prevention of mental disorders within a campus environment.

Strengths and limitations

To the best of our knowledge, this is the first study investigating the roles of resilience and exercise tolerance in the associations between PA and negative emotions. Promising findings from the chain mediation model indicate a novel psychological mechanism underlying the effects of PA engagement on stress-related negative emotion. Several limitations of this study should be admitted. First, as this study focused on Chinese college students, its findings may not be applicable to the other age groups with or without chronic illnesses such as adolescents and those who are experiencing heavy academic load (particularly in the Chinese educational system) as well as older adults who often reported loneliness. Second, the mediation model was examined cross-sectionally, which prevents us from drawing conclusions on causality. Third, online self-assessments and snow-ball sampling may have affected the representativeness and reliability of the results. Lastly, although this study clarified the relationship between PA and emotional states in college students and confirmed the mediating role of resilience and exercise tolerance, it did not rule out the existence of other intermediary variables. For example, Ready et al. (2009) found that PA level can have an indirect impact on emotional states through sleep quality. Thus, sleep quality may also have a mediating effect on the association of regular PA and emotional states, which needs to be investigated further. Additionally, we recommend that future research uses a longitudinal design to test the validity of our cross-sectional findings. Given the consistent results of PA and CRF (cardiorespiratory fitness) supported in many studies, future studies can explore the relationship between CRF and these variables, including negative emotional states, resilience and intensity-tolerance.

Conclusion

Given the increasingly serious situation of depression, anxiety and stress among college students, the relationship between such negative emotional states and PA is receiving increased attention from scholars and practitioners. To

better understand the relationship between PA and negative emotional states, a number of psychological factors need to be taken into account such as exercise tolerance and resilience. The present study suggests that PA can predict negative emotional states indirectly through exercise tolerance and resilience. The results of this study encourage college students to get into the habit of regular PA which provides a new perspective for the prevention of mental disorders within a campus environment.

Declaration of Competing Interest

The authors declare that they have no competing interests.

Acknowledgments

This study is supported by Start-up Research Grant of Shenzhen University (20200807163056003) and Start-Up Research Grant (Peacock Plan: 20191105534C)

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