BIDIRECTIONAL-PREDICTIVE EVIDENCE-BASED STUDY ON DAILY PHYSICAL ACTIVITY AND EMOTIONAL STATES OF PHYSICAL-EDUCATION MAJOR UNDERGRADUATES

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Abstract. Though regular physical-activity promotes physical-mental well-being, undergraduates’ activity levels remain unsatisfactory. This study investigates bidirectional relationships between daily physical-activity and emotional states of physical-education majors. 219 valid participants from Tianjin University of Sport completed measurements with the GT3X+ accelerometer and Daily Mood Scale. Correlation, Harman’s single-factor and Mplus-based cross-lagged analyses were conducted. Physical-activity correlated positively with positive emotions ($P < 0.01$) and negatively with negative emotions ($P < 0.05$). Bidirectional prediction was found between physical-activity and positive emotions. Physical-activity could not forecast negative emotions, but negative low-arousal emotion negatively predicted subsequent physical-activity. Physical-education majors show strong bidirectional links between physical-activity and positive emotions, with weak associations for negative emotions. Interventions shall attach importance to both exercise-derived emotional benefits and mood-driven activity improvement.

Keywords: *physical activity; emotional state; cross-lagged analysis; physical-education major; undergraduates*

Annotatsiya. *Physical activity is a general term for bodily movement defined by energy consumption generated by skeletal-muscle exercise. Regular physical-activity improves physical function and mental well-being, yet undergraduates’ physical-activity participation remains unsatisfactory. This paper explores the bidirectional correlation between daily physical activity and diverse emotional states of physical-education-major undergraduates, and provides theoretical basis for promoting their physical and mental health. An intensive longitudinal design was*

adopted with GT3X+ tri-axial accelerometer and Chinese version of Daily Mood Scale for data collection, and cross-lagged analysis was used to test the reciprocal predictive relationships. Research results show that physical activity has significant bidirectional predictive association with positive emotions, while the bidirectional link with negative emotions is weak. Intervention measures should attach importance to emotional benefits of physical activity as well as the growth of physical-activity participation caused by improved emotional states.

Kalit so‘zlar: *jismoniy faollik; hissiy holat; kross-lag tahlili; jismoniy tarbiya mutaxassisligi; oliy ta’lim talabalari*

Аннотация. *Физическая активность-это обобщающее понятие двигательной деятельности, которая сопровождается расходом энергии скелетных мышц. Регулярная физическая активность улучшает физическое и психическое состояние, но уровень физической активности современных студентов остаётся низким. В статье исследуется двусторонняя прогностическая взаимосвязь между повседневной физической активностью и разными эмоциональными состояниями студентов-физкультурников. Сбор данных проводился с помощью трехосевого акселерометра GT3X+ и китайской версии шкалы повседневных настроений, для проверки взаимовлияний применялся кросс-лагговый анализ. Результаты демонстрируют выраженную двустороннюю связь физической активности с положительными эмоциями и слабую-с отрицательными. При разработке оздоровительных программ необходимо учитывать как эмоциональные эффекты физических нагрузок, так и повышение двигательной активности на фоне улучшения эмоционального состояния.*

Ключевые слова: *физическая активность; эмоциональное состояние; кросс-лагговый анализ; специальность физического воспитания; студенты-вузовцы*

Introduction. Physical activity is a general term for bodily movement, defined by energy expenditure generated by skeletal-muscle exercise. Studies have confirmed that regular physical activity produces significant improvements in individuals’ physical and mental health. Nevertheless, the current physical-activity status of university students remains unsatisfactory. Therefore, it has become an urgent research question

to identify approaches for promoting physical-activity participation and supporting long-term adherence.

Existing studies have demonstrated bidirectional associations between physical activity and psychological responses: physical activity plays a beneficial role in alleviating negative emotions such as anxiety and depression; improved emotional states in turn serve as motivational drivers for individual physical-activity participation. However, opposite viewpoints also exist in relevant literature: some studies report no significant correlation between physical activity and negative emotions. Adopting an intensive longitudinal design, this study explores the bidirectional associations between daily physical-activity levels and daily emotional states among physical-education-major undergraduates. It aims to provide theoretical basis and empirical evidence for the promotion of undergraduates’ physical activity, the development of emotion-regulation theory in sport science, and practical strategies for exercise-based emotion regulation.

Literature analysis. Prior cross-sectional studies can only test concurrent correlations, and cannot disentangle the temporal reciprocal relationships between physical activity and emotion. Intensive longitudinal designs enable repeated assessment of participants’ daily real-life behaviours. Existing empirical findings confirm that physical activity can increase subsequent positive affect and mitigate negative affect, while emotional states can motivate or inhibit subsequent physical-activity engagement.

Relevant theoretical frameworks include the cerebral lateralization hypothesis, neurotransmitter hypothesis, embodied-cognition theory and self-determination theory. The cerebral lateralization hypothesis holds that exercise activates the left-hemisphere approach system and suppresses the right-hemisphere withdrawal system, thus increasing positive emotions and reducing negative emotions. Neurotransmitter hypotheses suggest that physical activity boosts cerebral blood flow and facilitates the release of dopamine, serotonin and other neurotransmitters, which further modulate emotional experience. Embodied-cognition theory indicates that cognitive and emotional responses arise from interactions between bodily states and external stimuli. Self-determination theory highlights autonomous motivation as a critical intermediate factor linking physical activity and emotional experience.

Empirical literature points out that emotional arousal level produces progressive effects under behavioural intervention; under memory-mechanism effects, repeatedly-stimulated emotional states can be rapidly retrieved and subjectively

consolidated. High-arousal negative emotions are often episodic and context-dependent with short duration, whereas low-arousal negative emotions tend to be persistent. Existing research also notes that weekday-weekend differences moderate physical-activity patterns.

Most previous research targets general adult or ordinary-student samples. Few studies separate four categories of emotions (positive high-arousal, positive low-arousal, negative high-arousal, negative low-arousal) and test their differential bidirectional predictive effects specifically for physical-education-major undergraduates. The present study fills this gap. Limitations remain: the current sample only covers physical-education-major undergraduates; future research should test whether time dimensions exert moderating effects and compare findings with non-physical-education student populations.

Research object and applied methods. The research object is bidirectional predictive relationships between objectively-measured daily physical-activity volume and four types of emotional states among physical-education-major undergraduates. This research is restricted to course-of-day physical activity and daily self-reported emotional states. It excludes AI-related topics, scientific publications and university administrative management.

Subject recruitment and testing were conducted from early May to late June 2022 among physical-education-major undergraduates at Tianjin University of Sport. Based on standards for adult physical-activity data collection, data were collected for 7 consecutive days. According to prior research paradigms and analytical prerequisites, valid statistical analysis required at least three consecutive valid days (two weekdays plus one rest day), namely Thursday, Friday and Saturday. Exclusion criteria: participants with exercise contraindications, diagnosed physical or mental illnesses unsuitable for testing, and participants whose data failed validity standards and declined retesting. A total of 219 valid samples were obtained (114 males, 105 females), mean age 21.2 ± 0.5 years. Ethical approval was granted by the Ethics Committee of Tianjin University of Sport (approval No. TJUS2022-026). Informed consent was obtained from all participants.

Physical-activity data were collected via GT3X+ tri-axial accelerometer. Wearing requirement: fastened on the right iliac crest; removed only for bathing and swimming. Wearing period: 7 consecutive days, 08:00-22:00. Instrument setting: sampling frequency 100 Hz, epoch interval 5 seconds. Physical-activity output expressed in MET values, calculated by the Freedson Adult (1998) algorithm embedded in ActiLife:

kcal/(kg·h). Validity criteria for data: minimum 10 hours of wear-time during waking hours counts as one valid day; at least three valid days required. Retesting was performed with participant consent if data did not meet standards.

The Daily Mood Scale originally developed by Ivarsson et al. was translated into Chinese and back-translated with double-blind procedures. Revisions were made for Chinese linguistic context. Multiple pilot tests yielded the final Chinese-language Daily Mood Scale. The scale contains 12 items across four emotional dimensions, adopting VAS scoring ranging from 0 (strongly disagree) to 100 (strongly agree). Instructions asked participants to evaluate emotional words by reflecting on their experience of the whole day. Each dimension contained three items: positive high-arousal (excited, joyful, happy); positive low-arousal (calm, relaxed, satisfied); negative high-arousal (tense, angry, sorrowful); negative low-arousal (fatigued, depressed, bored). Cronbach’s α coefficients for pilot testing: positive high-arousal 0.829, positive low-arousal 0.810, negative high-arousal 0.763, negative low-arousal 0.792; overall scale 0.774, test-retest reliability 0.704, with satisfactory construct validity. Emotional questionnaires were distributed online and completed between 21:30-22:00 each day.

ActiLife software processed raw accelerometer outputs, which were further organized in Excel. SPSS 25.0 was used for scale-reliability testing, descriptive statistics and Pearson correlation analysis. Mplus 7.4 performed cross-lagged analysis to test bidirectional associations between daily physical activity and different emotional states. The significance threshold α was set at 0.05.

Results and their analysis. Harman’s single-factor test was applied for common-method-bias examination for data entering structural-equation-modelling analysis. According to Podsakoff’s criteria, no serious common-method bias exists if more than one principal component has an eigenvalue greater than 1 and the first principal component explains less than 40 % of total variance. Unrotated exploratory-factor analysis extracted seven factors with eigenvalues greater than 1. The first factor explained 27.56 % of variance, below the critical value of 40 %, indicating no severe common-method bias in this study.

Pearson correlation analysis demonstrated that physical-activity volume was significantly positively correlated with positive emotions and significantly negatively correlated with negative emotions. Positive high-arousal emotion was significantly positively correlated with positive low-arousal emotion and significantly negatively correlated with negative emotions. Negative high-arousal emotion was significantly positively correlated with negative low-arousal emotion. Intra-class correlation

coefficient (ICC) was calculated to avoid memory-driven repeated responses. ICC values ranged from 0.34 to 0.63, all below 0.75, which indicated low repetition in data and sufficient day-to-day variance to satisfy prerequisites for cross-lagged analysis.

Physical-activity volume was taken as an observed variable. The total score of three items (excited, joyful, happy) representing positive high-arousal emotion served as latent variable to construct mixed cross-lagged model. Model fit indices: $\chi^2 = 90.59$, $\chi^2/df = 1.97$, CFI = 0.98, TLI = 0.97, RMSEA = 0.07, indicating good model fit. Autoregressive coefficient from Thursday physical-activity volume to Friday physical-activity volume was positive ($\beta = 0.12$, $P < 0.05$). Friday physical-activity volume showed no significant correlation with positive high-arousal emotion on the same day ($\beta = 0.14$, $P = 0.22$). All other correlations among indicators were significantly positive ($P < 0.01$).

Physical-activity volume was treated as observed variable; total score of three items (calm, relaxed, satisfied) representing positive low-arousal emotion was set as latent variable for mixed cross-lagged modelling. Fit indices: $\chi^2 = 113.95$, $\chi^2/df = 2.48$, CFI = 0.93, TLI = 0.90, RMSEA = 0.08, good model fit. Friday physical-activity volume was positively correlated with positive low-arousal emotion on the same day ($\beta = 0.26$, $P < 0.05$). Friday physical-activity volume showed marginal weak correlation with Saturday positive low-arousal emotion ($\beta = 0.14$, $P = 0.06$). All other indicator correlations were significantly positive ($P < 0.01$).

Physical-activity volume was observed variable; total score of three items (tense, angry, sorrowful) for negative high-arousal emotion was latent variable for mixed cross-lagged model. Fit indices: $\chi^2 = 110.57$, $\chi^2/df = 2.40$, CFI = 0.95, TLI = 0.93, RMSEA = 0.08, good fit. No significant predictive effect existed between physical-activity volume and negative high-arousal emotion ($P > 0.05$). Friday physical-activity volume showed no significant correlation with same-day negative high-arousal emotion ($\beta = -0.04$, $P = 0.68$). Remaining indicator correlations were extremely significant ($P < 0.01$).

Physical-activity volume was observed variable; total score of three items (fatigued, depressed, bored) for negative low-arousal emotion was latent variable for mixed cross-lagged model. Fit indices: $\chi^2 = 114.87$, $\chi^2/df = 2.50$, CFI = 0.94, TLI = 0.90, RMSEA = 0.09, good fit. Physical-activity volume on the preceding day exerted no predictive effect on negative low-arousal emotion on the subsequent day ($P > 0.05$). Negative low-arousal emotion of the preceding day significantly negatively predicted physical-activity volume on the next day ($P < 0.01$). Friday physical-activity volume

had no significant correlation with same-day negative high-arousal emotion ($\beta = -0.04$, $P = 0.31$). Autoregressive coefficient from Thursday negative low-arousal emotion to Friday negative low-arousal emotion was positive ($\beta = 0.25$, $P < 0.05$). Other indicator correlations showed extreme significance ($P < 0.01$).

In summary, daytime physical-activity level was positively correlated with nocturnal positive emotions and negatively correlated with nocturnal negative emotions. Bidirectional predictive effects existed between physical activity and both positive-high-arousal and positive-low-arousal emotions. Physical-activity volume could not predict subsequent negative emotions, yet negative low-arousal emotion exerted predictive effect on subsequent physical-activity volume.

Discussion. Against the background of Healthy-China initiative, promoting physical and mental health deserves high priority. Many existing studies adopt cross-sectional paradigms and overlook continuous developmental trajectories of physical-activity and emotional variables. This study applied intensive longitudinal design to repeatedly assess participants’ daily real-world behaviours. Cross-lagged design was used to explore longitudinal relationships between physical-activity volume and different emotional categories across multiple time points, aiming to verify reciprocal effects between physical activity and emotion, enrich exercise-emotion-regulation theory and provide evidence for sustaining physical-activity adherence.

Multi-day aggregate analysis showed that daily physical activity increased subsequent-evening positive affect and inhibited evening negative affect, consistent with previous research findings. From psychological perspective, human beings possess two basic emotional systems: the approach-system regulated by the left cerebral hemisphere and the withdrawal-system regulated by the right cerebral hemisphere. The cerebral-lateralization hypothesis supports that exercise activates the left hemisphere and de-activates the right hemisphere, thus increasing positive emotions and reducing negative emotions.

This study found special temporal features: Friday physical-activity volume was relatively low. Participants tended to reduce activity before weekends to relieve accumulated fatigue and obtain rest, and Friday-night emotional states were dominated by positive low-arousal emotions (calm, relaxed, satisfied). Therefore, correlations between physical activity and emotion may differ across time segments. Future research should further examine whether time dimension acts as a moderator.

Significant bidirectional prediction existed between physical activity and both positive-arousal dimensions. The progressive-effect mechanism of emotional arousal and memory-consolidation mechanism can partly explain this finding. Embodied-cognition theory also supports mutual influence between physical behaviour and emotional arousal. For physical-education-major undergraduates, even without formal training schedules, they tend to take exercise driven by autonomous motivation. This aligns with self-determination theory and hedonistic theories in sport psychology: autonomous motivation may serve as potential mediator strengthening hedonic experience during and after exercise and forming positive feedback loops. For non-physical-education populations, autonomous motivation may play different mediating roles, which awaits further investigation.

No bidirectional association was detected between physical activity and negative high-arousal emotion, consistent with prior literature. Under conditions of high physical and mental load, high-arousal negative emotions are easily triggered but tend to be transient, and their triggering contexts are complex. For healthy young-adult university-student samples, baseline levels of negative high-arousal emotion are generally low, leading to non-significant cross-day correlations. In contrast, negative low-arousal emotions (fatigue, depression, boredom) are sustained states less controlled by subjective consciousness. The results indicated that negative low-arousal emotion exerted dominant predictive influence on subsequent physical-activity reduction.

Neurophysiological explanations include neurotransmitter hypotheses: physical activity enhances cerebral blood flow and promotes release of dopamine, serotonin and other neurotransmitters, which underpins connections between physical activity and emotional experience.

Overall, physical activity helps boost positive emotions and mitigate negative emotions; improved emotional states in turn motivate physical-activity engagement and long-term adherence. In contexts of widespread insufficient physical activity, greater attention should be paid to emotional benefits generated by exercise, not merely physical-health gains.

This study has certain limitations. It only adopted observational data analysis, and the sample was limited to physical-education-major undergraduates of one sport-specialized university. It did not compare samples of ordinary undergraduates, nor test mediating variables such as autonomous motivation. Future research should test moderating effects of time-related factors and extend sampling scope to non-physical-education-major undergraduates.

Conclusion. Daytime physical activity correlates positively with nocturnal positive emotions and negatively with nocturnal negative emotions. Significant bidirectional predictive associations exist between daily physical-activity volume and positive emotions among physical-education-major undergraduates; bidirectional correlations with negative emotions are weak. Physical activity cannot predict subsequent negative-emotion changes, whereas prior-day negative low-arousal emotion negatively predicts later physical-activity volume.

To improve adherence to physical activity and emotional status, interventions should attach importance both to emotional benefits generated by physical activity and to increments in physical-activity participation driven by improved emotional states. Follow-up research may explore the moderating effect of different time dimensions and compare the effect among non-physical-education-major populations.

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