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ORIGINAL ARTICLE

Observational Study

# Correlation and pathways of behavioral activation systems mediating physical activity level and depressive symptoms among college students

Jiang-Hua Zhu, Shu-Fan Li, Peng Wang, Xin Xin, Qun Zhao, Si-Cheng Chen, Xing Wang

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## Abstract

*BACKGROUND*

Depression is a common mental disorder among college students. The main symptoms include being persistent low mood, sad emotional experiences, lack of pleasure, listlessness, and impaired cognitive function accompanied by tendencies of self-harm and suicide.

*AIM*

To clarify the pathways and effects of the behavioral activation system between physical activity and depressive symptoms in college students with depressive symptoms.

*METHODS*

This cross-sectional research screened 3047 college students. Of these, 472 had depressive symptoms, with a depression detection rate of 15.49%. Furthermore, 442 college students with depressive symptoms were analyzed. A one-way analysis of variance and Pearson's correlation, linear regression, and structural equation modeling analyses were used to explore the correlations and pathways of the interactions between the variables.

*RESULTS*

Depressive symptoms were significantly negatively correlated with physical activity (r = -0.175, $P < 0.001$), the behavioral activation system (r = -0.197, $P < 0.001$), and drive (r = -0.113, $P = 0.017$). Furthermore, it was negatively correlated with fun-seeking (FS) (r = -0.055, $P = 0.251$); however, it was not significant. Physical activity was significantly positively correlated with reward respons-

iveness (RR) (r = 0.141, *P* = 0.003) and drive (r = 0.124, *P* = 0.009) and not significantly positively correlated with FS (r = 0.090, *P* = 0.058). The mediating effect of RR between physical activity and depressive symptoms was significant [B = -0.025, 95% confidence interval (95%CI): -0.051 to -0.008, *P* = 0.001]. The direct and total effects of physical activity on depressive symptoms and were significant (B = -0.150, 95%CI: -0.233 to -0.073, *P* < 0.001; B = -0.175, 95%CI: -0.260 to -0.099, *P* < 0.001), respectively.

*CONCLUSION*

As physical activity levels increased, depression scores among college students decreased. The mediating effect of RR between physical activity and depressive symptoms was significant. Therefore, colleges and universities should encourage college students with depression to increase their physical activity and improve their behavioral activation system. Particular attention should be paid to RR, which may reduce the prevalence of depressive symptoms.

**Key Words:** College students; Physical activity; Depressive symptoms; Behavioral activation system; Mediating role



**Core Tip:** This study explored the specificity of the behavioral activation system for physical activity and reward motivation in college students with different depressive symptom scores. Furthermore, the inter-relationships among the three variables were examined *via* a cross-sectional research design. Pathways of the behavioral activation system that mediated the effect of physical activity level on depressive symptoms in college students with depressive symptoms were clarified.

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## INTRODUCTION

Depression, a disabling mental disorder, seriously endangers the lives and health of people and ranks the 13th highest in the number of disability-adjusted life-years among all illnesses and injuries worldwide[1]. It is a common mental disorder among college students, with a detection rate of over 30%[2,3]. The main symptoms include persistent low mood, sad emotional experiences, lack of pleasure, listlessness, and impaired cognitive function, with tendencies of self-harm and suicide. The World Health Organization predicted that depression would rank first in the disease burden worldwide by 2030[4].

The behavioral activation system, also known as reward motivation, is located in the midbrain dopamine loop and refers to the convergent motivation for reward, promoting goal-directed behavior to obtain the reward, and producing positive emotions or hedonic pleasure experiences[5]. It is divided into three factors: Reward responsiveness (RR), drive, and fun-seeking (FS)[6]. Impaired reward function, or anhedonia, is a core symptom of depression, and deficits in the behavioral activation system can serve as functional deficits in depressive symptoms[7,8].

An inter-relationship between physical activity, depressive symptoms, and behavioral activation system exists. Appropriate physical activity significantly alleviates clinical symptoms in people with depressive symptoms[9-11] and reduces anxiety and depression levels in college students[12]. In addition, exercise is also strongly associated with behavioral activation system, such as enhancing the midbrain-striatal dopamine (DA) system and improving the brain reward function in adolescents[13]. Physical activity also positively affects the behavioral activation system, and thereby alleviates depressive symptoms.

Previous studies[7-11,13] examined the two-sided relationship between physical activity, behavioral activation system, and depressive symptoms. Physical activity enhanced the behavioral activation system and reduced depressive symptoms. Furthermore, the behavioral activation system acted as an influencing factor for depressive symptoms. However, whether the behavioral activation system intervened in the relationship between physical activity and depressive symptoms remains unclear. Furthermore, its pathways of actions, how it intervened through the three subdimensions of the behavioral activation system, and whether the effects were consistent also remain unclear. Therefore, this study conducted a cross-sectional research that aimed to provide a theoretical basis for a deeper understanding of the relationship between human behavior, emotion, and the nervous system. Furthermore, we aimed to provide a reference for researchers and college administrators. This study proposed the following research hypotheses: (1) Physical activity and the behavioral activation system would have specificity among college students with different depressive symptom scores; (2) Physical activity, the behavioral activation system, and depressive symptoms would be closely related; and (3) Behavioral activation system would mediate the relationship between physical activity and depressive symptoms with different effects of the sub-dimensions.

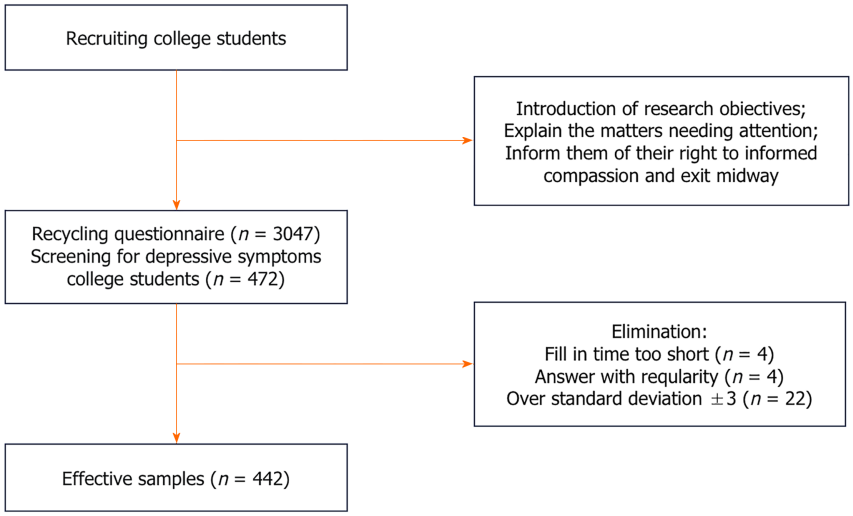


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**Figure 1 Flow chart of the participants recruitment.**

## MATERIALS AND METHODS

### Participants

This study used a cross-sectional research design. In total, 3047 college students were recruited online based on voluntary participation to complete a questionnaire. College students with depressive symptoms were screened *via* the Beck Depression Inventory (BDI)-II, and 472 students had depressive symptoms, with a depression detection rate of 15.49% (Figure 1). Inclusion criteria were participants who were college students, aged 18-26 years, had a score of ≥ 14 on the BDI-II, with a scores of 14-19, 20-28, and 29-63 indicating mild, moderate, and severe depression, respectively, and had no other psychiatric disorders and no brain injury. The exclusion criteria were participants who took drugs, such as barbiturates, benzodiazepines, and chloral hydrate, majored in sports, and had contraindications for exercise. After 30 invalid questionnaires with regular responses, a short response time (< 3 min), or outliers that exceeded the standard deviation ± 3 were excluded, 442 valid questionnaires (93.64%) were obtained. This study was approved by the Ethics Committee of the Shanghai University of Sport (102772021RT007).

### Measures

**General information questionnaire:** Participants' basic information, such as age, sex, height, weight, and family status were obtained.

**International physical activity questionnaire short form:** This 7-item questionnaire has been widely used to measure physical activity among Chinese university students. Of these, six questions enquired regarding individuals' physical activity, which included high-intensity and moderate-intensity physical activity, and walking, and the frequency of different intensity activities for one week and the cumulative time per day. The weekly physical activity levels were calculated and divided into high, medium, and low groups according to the relevant criteria. The higher the group level, the greater the intensity of daily physical activity. This scale's retest reliability coefficient was 0.718[14].

**Behavioral inhibition/activation system scale:** A revised Chinese version by Li *et al*[15] was adopted with 18 items, which included two dimensions: Behavioral inhibition and activation. The behavioral activation dimension, also known as the behavioral activation system, was selected and contained three subfactors: RR, drive, and FS. Each item was scored on a scale from 1 (fully agree) to 4 (fully disagree). Cronbach's alpha was 0.759[15].

**BDI-II:** This widely used 21-item self-assessment scale assessed depressive symptoms. Responses were rated on a 4-point Likert scale that ranged from 0 (no symptoms) to 3 (severe symptoms). Total scores of 0-13, 14-19, 20-28, and 29-63 indicated no, mild, moderate, and severe depression, respectively. The internal consistency coefficient was 0.948[16].

### Statistical analysis

Measures were expressed as mean ± SD, and the results were retained to three decimal places. For questionnaire data that were not missing at random, interpolation of the means of the same category was performed to avoid biased estimated coefficients *via* the simple deletion method. One-way analysis of variance and least significant difference post-hoc multiple tests were applied to compare the specificity of physical activity and behavioral activation system among college students with different depressive symptom scores. Pearson's correlation and linear regression analyses were performed to explore the relationships among physical activity, depressive symptoms, and behavioral activation system. Two-tailed tests were adopted for statistical inference of all parameters, and the test level α was set at 0.05. $P < 0.05$, $P < 0.01$, and $P < 0.001$ all indicated statistical significance.

**Table 1 Differences in physical activity and behavioral activation system in college students with different depressive symptom scores**

| Variables | Whole (442) | Levels of depressive symptoms | | | F-value | *P* value | Post hoc multiple comparisons | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Severe (*n* = 58) | Moderate (*n* = 190) | Mild (*n* = 194) | | | Severe *vs* Moderate | Severe *vs* Mild | Moderate *vs* Mild |
| Physical activity (MET-min/week) | 1308 ± 954 | 944 ± 617 | 1333 ± 1003 | 1392 ± 967 | 5.149 | 0.006 | 0.006 | 0.002 | 0.535 |
| Reward responsiveness | 11.88 ± 2.033 | 11.03 ± 2.232 | 11.81 ± 2.043 | 12.21 ± 1.885 | 7.865 | < 0.001 | < 0.001 | 0.010 | 0.053 |
| Drive | 11.22 ± 2.064 | 10.71 ± 2.656 | 11.15 ± 2.008 | 11.45 ± 1.888 | 3.129 | 0.045 | 0.154 | 0.016 | 0.152 |
| Fun-seeking | 14.17 ± 2.270 | 13.78 ± 2.968 | 14.10 ± 2.217 | 14.36 ± 2.067 | 1.654 | 0.192 | 0.341 | 0.085 | 0.260 |

**Table 2 Regression analysis of each variable**

| Independent variables | B | 95%CI | | Beta | Coefficient significance test | | SE | Collinearity diagnostics | |
|---|---|---|---|---|---|---|---|---|---|
| | | Lower limit | Upper limit | | *t*-value | *P* value | | Tolerance | VIF |
| Reward responsiveness | -0.176 | -0.268 | -0.084 | -0.176 | -3.766 | < 0.001[a] | 0.047 | 0.980 | 1.020 |
| Physical activity | -0.116 | -0.242 | -0.058 | -0.116 | -3.217 | 0.001 | 0.047 | 0.980 | 1.020 |

[a]*P* < 0.001.

Model summary: F = 14.259[a]; R = 0.247; $R^2$ = 0.061; Adjusted $R^2$ = 0.057. VIF: Variance inflation factor; 95%CI: 95% confidence interval.

Harman's single factor test was used to examine the effects of common method bias. Structural equation modeling was conducted to examine the role of behavioral activation system in mediating the relationship between physical activity and depressive symptoms. The non-parametric percentage bootstrap method was adopted for parameter estimation in the path analysis. Number of samples was set at 5000, with a bias-corrected 95% confidence interval (95%CI) for the product of the mediated paths, without 0 defining the mediating effect as statistically significant. Data calculations were performed using SPSS Statistics version 23.0, and Amos version 23.0.

## RESULTS

### *Specificity of physical activity and behavioral activation system in college students with different depressive symptom scores*

There were no significant differences in FS behavior, physical activity, RR, and drive ($P < 0.05$) among college students with different depressive symptom scores. Post-hoc multiple comparisons indicated significant differences in physical activity and RR ($P < 0.05$) between college students with severe depressive symptoms and those with moderate depressive symptoms. In addition, there were also differences in physical activity, RR, and drive ($P < 0.01$) between those with severe depressive symptoms and those with mild depressive symptoms. Other indicators had no statistically significant differences. See Table 1 for further details.

### *Relationship between physical activity, depressive symptoms and behavioral activation system*

Depressive symptoms were significantly negatively correlated with physical activity (r = -0.175, $P < 0.001$), RR (r = -0.197, $P < 0.001$), and drive (r = -0.113, $P = 0.017$). Furthermore, it was also negatively correlated with FS (r = -0.055, $P = 0.251$); however, it was not significant. Physical activity was significantly positively correlated with RR (r = 0.141, $P = 0.003$) and drive (r = 0.124, $P = 0.009$), and not significantly positively correlated with FS (r = 0.090, $P = 0.058$). Further details are shown in Figure 2.

To examine the extent of which physical activity and behavioral activation system explained depressive symptoms and explore the feasibility of the structural relationship model, depressive symptoms were considered as dependent variables, and physical activity, RR, drive, and FS as independent variables. Furthermore, a linear regression analysis was performed *via* stepwise regression. The goodness-of-fit of the prediction model was demonstrated (R = 0.247, $R^2$ = 0.061, adjusted $R^2$ = 0.057, and changed variable F = 10.349), which excluded drive and FS. As shown in Table 2, RR and physical activity were negative influencing factors, with 6.1% explanatory power for depressive symptom scores. The tolerance of each independent variable was > 0.1, and the variance inflation factor was < 5; thus, the effect of multicollinearity was excluded.

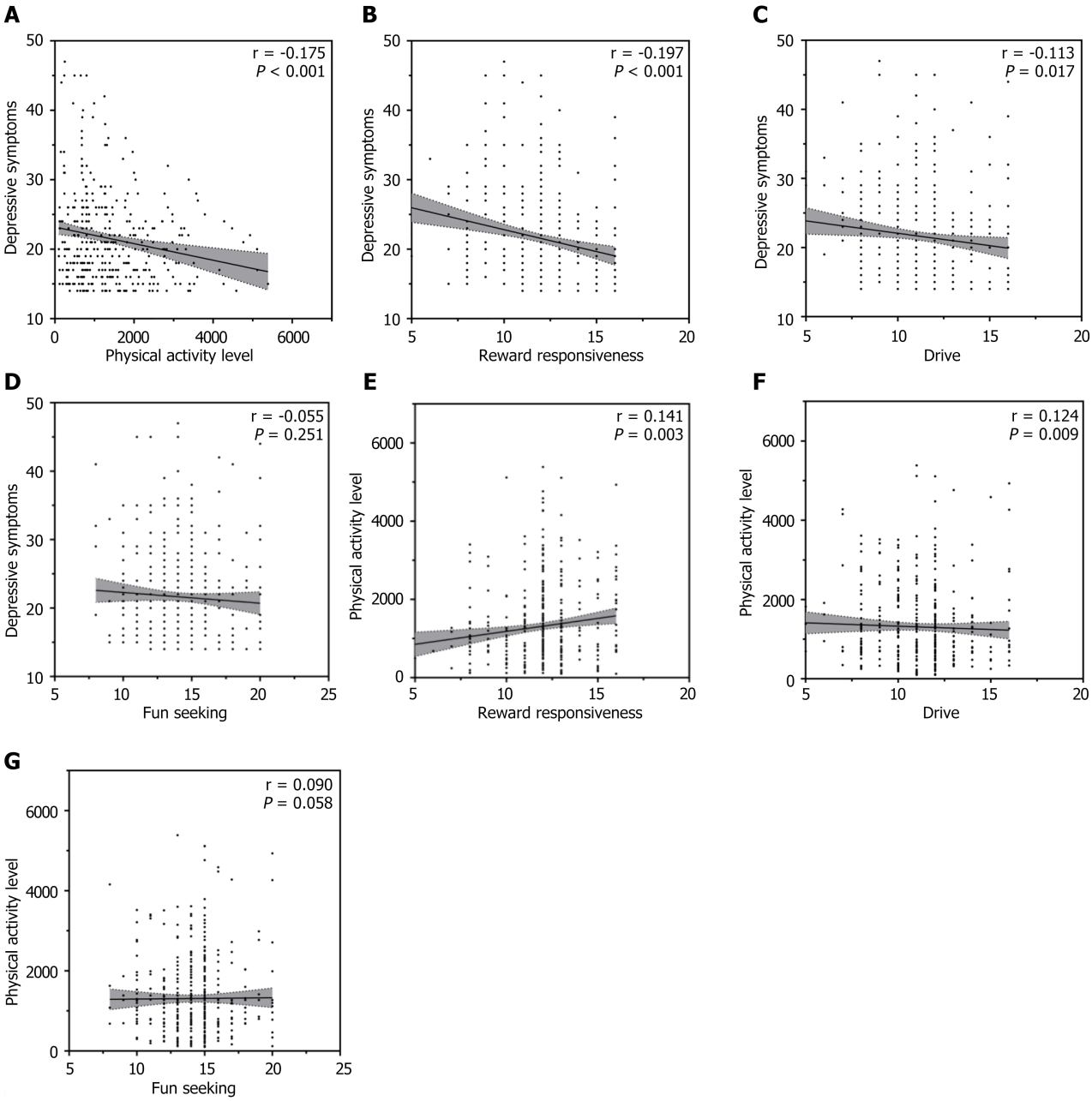


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**Figure 2 Correlations among the variables.** A: Depressive symptoms were significantly negatively correlated with physical activity; B: Depressive symptoms were significantly negatively correlated with reward responsiveness; C: Depressive symptoms were significantly negatively correlated with drive; D: Depressive symptoms were negatively, but not significantly, associated with fun-seeking; E: Physical activity was significantly positively correlated with reward responsiveness; F: Physical activity was significantly positively correlated with drive; G: Physical activity were positively, but not significantly, associated with fun-seeking.

### *Construction and validation of a structural relationship model of indicators of physical activity, behavioral activation system, and depressive symptoms*

To assess for common method bias, a validation factor analysis was conducted on the International Physical Activity Questionnaire, the Behavioral Activation System Scale, and the BDI *via* Harman's single factor test, nine factors with characteristic roots greater than 1 were obtained. The amount of variance explained by the first factor was 17.980%, which was less than the critical value of 40%. Therefore, the effect of common method bias was excluded. Based on the inter-relationships among physical activity, behavioral activation system, and depressive symptoms in college students, a model was established with physical activity, depressive symptoms, and behavioral activation system as the independent, dependent, and mediating variables, respectively. Mediated paths with insignificant coefficients were individually removed and recalculated until all mediated path coefficients passed the bootstrap significance test. Discrepancies divided by degrees of freedom (CMIN/df) = 0.286, root mean square residual (RMR) = 0.006, root mean square error of approximation (RMSEA) < 0.001, goodness-of-fit index (GFI) = 1.000, normed fit index (NFI) = 0.999, and comparative fit index (CFI) = 1.000 reached the reference standards of CMIN/df < 3, RMR < 0.05, RMSEA < 0.08, GFI, NFI, and CFI > 0.9[17], which indicated that the structural equation model fit well and was reasonable and reliable. The

**Table 3 List of the intermediary effect coefficients**

| Types of effects | B | SE | Bias-corrected 95%CI | | |
|---|---|---|---|---|---|
| | | | Lower limit | Upper limit | *P* value |
| Mediating effect of reward responsiveness | -0.025 | 0.011 | -0.051 | -0.008 | 0.001 |
| Path coefficient of physical activity on drive | 0.124 | 0.045 | 0.034 | 0.211 | 0.007 |
| Direct effect | -0.150 | 0.041 | -0.233 | -0.073 | < 0.001 |
| Total effect | -0.175 | 0.040 | -0.260 | -0.099 | < 0.001 |

95%CI: 95% confidence interval.

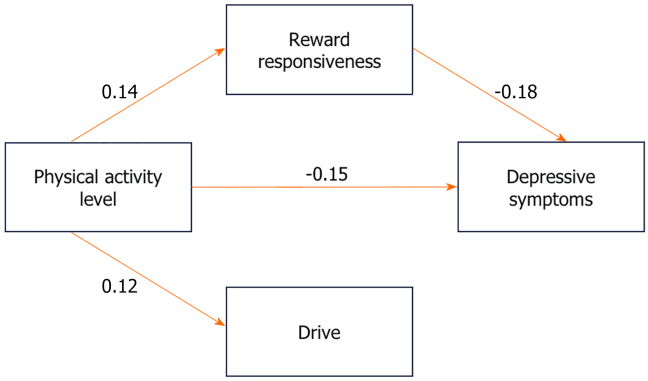


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**Figure 3 Schematic diagram of the structural relationship model between physical activity, behavioral activation system, and depressive symptom indicators in college students with depressive symptoms.** There are direct pathways and reward responsiveness-mediated indirect pathways between physical activity and depressive symptoms.

path analysis is shown in Figure 3, and the results of the mediating effect test are presented in Table 3. The path coefficients of physical activity on FS were not significant. Furthermore, those of FS and driving on depressive symptom scores were not significant, and were excluded. There were significant path coefficient for physical activity on drive (B = 0.124, 95%CI: 0.034 to 0.211, $P$ = 0.007), mediating effect mediated by RR (B = -0.025, 95%CI: -0.051 to -0.008, $P$ = 0.001), direct effect of physical activity on depressive symptoms (B = -0.150, 95%CI: -0.233 to -0.073, $P$ < 0.001), and total effect of physical activity on depressive symptoms (B = -0.175. 95%CI: -0.260 to -0.099, $P$ < 0.001).

## DISCUSSION

These results showed that the higher the level of physical activity among college students with depressive symptoms, the higher the behavioral activation system and lower their depressive symptom scores. Furthermore, the direct effect of physical activity on depressive symptoms was significant. The results supported those of previous studies on the relationship between behavioral activation system and depressive symptoms. Furthermore, our findings were generally consistent with previous results. Takagaki *et al*[18] found a negative association between the behavioral activation system and depressive symptoms among 18-19 years old college students with depressive symptoms in a Japanese University. Absence of pleasure was a core symptom of depression[19] which was related to the dysfunction of the brain's DA reward system[20]. Deficits in the reward system served as a susceptibility factor and predictor of depression, with state independence and heritability[21,22]. A cross-sectional study found that college students with higher levels of physical activity had lower detection rates of depressive symptoms and insufficient physical activity was a risk factor for depressive symptoms among college students. Experimental studies confirmed that increased physical activity was effective in improving depressive symptoms and stimulated the secretion of neurotransmitters, which increased the behavioral activation system and also alleviated depressive symptoms.

This study showed that only RR mediated the relationship between physical activity and depressive symptoms. Physical activity promoted the secretion of neurotransmitters, such as DA in the brain, enhanced the neuroplasticity of the DA system, and improved the reward function. This enhanced the RR and contributed to the maintenance and regulation of good emotions in individuals, promoted the generation of positive emotions, and suppressed negative emotions[23]. High reward responses acted as a protective factor against depression[24]. Furthermore RR purely reflected extroversion and convergent motivation[25], which maintained and regulated individual behavior. Hence, impulsive behaviors that met short-term interests were subordinated to needs more closely related to the individual's long-term

interests[26]. High RR prompted a positive response to rewards. It enhanced an individual's ability to obtain pleasurable experiences to avoid the exacerbation of their depressive symptoms[27,28]. Only the RR pathway mediated the relationship between physical activity and depressive symptoms. A possible reason was that RR, as the initial evaluation of reward, measured early "reward interest," "goal-drive", and "persistence." Furthermore, its effect on depressive symptoms may precede the other two dimensions. Reasons why drive and FS did not mediate the relationship between physical activity and depressive symptoms were drive referred to the degree of willingness to exert effort to obtain a reward and measured late "reward responsiveness" and "impulsivity;" FS was a continuous evaluation of the reward. Hence, drive and FS were more significant for major depression, and better predictors of treatment effect[29,30]. Our participants had different conditions, and relatively few individuals reported severe depression symptoms.

This study has some limitations. First, the data were from subjective reports, which may have some bias. Furthermore objective indicators are recommended for future measurements. This study was conducted as a cross-sectional study. Hence, longitudinal studies are required to further confirm the pathways of action.

## CONCLUSION

The higher the level of physical activity, the higher the behavioral activation system and lower the depressive symptom score in college students with depression. Furthermore, there was only one pathway of action in the behavioral activation system, RR, which had a significant mediating effect between physical activity and depressive symptoms. Therefore, colleges and universities should encourage college students with depression to increase their physical activity and improve their behavioral activation system. Particular attention should be paid to RR, which may reduce the prevalence of depressive symptoms.

## ARTICLE HIGHLIGHTS

### *Research background*

Depression is a common mental disorder among college students. Key symptoms include persistent depressed mood, sad emotional experiences, lack of pleasure, listlessness, and impaired cognitive function, accompanied by self-harm and suicidal tendencies.

### *Research motivation*

Reduce the prevalence of depressive symptoms in college students.

### *Research objectives*

Elucidating pathways and effects of behavioral activation systems between physical activity and depressive symptoms in college students with depressive symptoms.

### *Research methods*

One-way analysis of variance and Pearson correlation, linear regression, and structural equation modeling were used to explore the correlation and pathway of interactions between variables.

### *Research results*

The mediating effect of reward responses between physical activity and depressive symptoms was significant [B = -0.025, 95% confidence interval (95%CI): -0.051 to -0.008, $P = 0.001$]. The direct and total effects of physical activity on depressive symptoms were significant ((B = -0.150, 95%CI: -0.233 to -0.073, $P < 0.001$; B = -0.175, 95%CI: -0.260 to -0.099, $P < 0.001$, respectively).

### *Research conclusions*

Colleges and universities should encourage college students with depression to increase physical activity and improve behavioral activation systems. Particular attention should be paid to the ability to reward responses, which may reduce the prevalence of depressive symptoms.

### *Research perspectives*

It is recommended to use objective measurement tools in future measurements; longitudinal studies are needed to further define the course of action.

## FOOTNOTES

**Author contributions:** Zhu JH wrote the original manuscript and collected the data; Li SF collected and analyzed the data; Wang P wrote part of the manuscript; Xin X collected the data; Zhao Q curated the data; Chen SC curated the data; Wang X reviewed and edited.

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