Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Depressive symptom networks across physical activity levels among junior high school students following the winter break: a cross-sectional network comparison analysis

Chenguang Fei

feichenguang@njxzc.edu.cn

Nanjing Xiaozhuang University

Xinyue Wang

Tangdian Middle School

Youxiang Cao

Nanjing Xiaozhuang University

Xuefeng Wang

Nanjing Xiaozhuang University

Research Article

Keywords: Network analysis, Winter break, Depressive, Physical activity, Chinese Junior high school students

Posted Date: November 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11616138/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Adolescent depression has become an increasingly serious public health challenge, and physical activity is one of the validated intervention approaches. During the winter break, their physical activity shifts from school-organized physical education to self-directed exercise, which may widen variations in overall activity levels. We therefore focused on this period to compare the depressive symptom networks across junior high school students with different physical activity levels and to examine how network features differed across these groups.

Methods

A cross-sectional dataset was obtained from 1,459 Chinese junior high school students following the winter break. Depressive symptoms were assessed using the 10-item Center for Epidemiological Studies-Depression Scale (CES-D-10). Based on self-reported physical activity and the World Health Organization (WHO) guideline for moderate-to-vigorous physical activity (MVPA), students were divided into Non-MVPA, Insufficient MVPA, and Sufficient MVPA groups. Depressive symptom networks were estimated using polychoric correlations and EBICglasso (gamma = 0.5), with strength and expected influence centrality computed. Network Comparison Tests (1000 permutations) compared network structure, global strength, edges, and centrality across the three MVPA groups, with Benjamini–Hochberg correction.

Results

No significant differences in network structure were observed between the Non-MVPA and Insufficient MVPA groups, but the Sufficient MVPA group showed a significantly distinct network. “Depressed” was the most central symptom across all three groups. The Sufficient MVPA group exhibited a specific rewiring: the edges linking “Lonely” to “Fearful”, “Effort”, and “Restless Sleep” weakened; the “Depressed” and “Lonely” edge strengthened; and the “Depressed” and “Get Going” edge shifted from positive to negative.

Conclusion

This study reveals a threshold pattern in the relationship between physical activity and depressive symptoms among junior high school students following the winter break. Interventions targeting central symptoms and strong edges may play a crucial role in the early prevention of depression. Furthermore, strategies aimed at providing guidance on physical activity during the break may be beneficial for safeguarding their mental health.

Introduction

Adolescents face multiple challenges during their junior high school years, including cognitive restructuring, peer network reconstruction, and identity formation [1]. These developmental tasks may heighten stress and emotional vulnerability, increasing the risk of depressive symptoms, which are among the most frequently reported internalizing problems in this population [2]. Globally, 21.3% of children and adolescents have experienced depression or depressive symptoms, and this proportion has continued to rise over recent decades [3]. Findings from studies in the United States [4], China [5], African countries [6], and other nations [7] collectively indicate that adolescent depression poses a severe and growing public health challenge in countries at different income levels. Depressive symptoms impair adolescents' academic performance [8] and social functioning [9], and they raise the risk of psychiatric disorder well into adulthood [10], Therefore, identifying modifiable behavioral factors associated with depressive symptoms in this age group is a priority for targeted prevention.

Physical activity (PA) is one such factor and can be targeted at the population level through school and community services [11]. Prospective evidence shows that engaging in regular PA correlates with a lower risk of developing depression among non-depressed adolescents [12]. For those already experiencing depressive symptoms, PA interventions have been shown to significantly relieve depressive symptoms compared to control conditions [13]. Researchers have also applied various research approaches to examine this relationship between PA and depressive symptoms. A large study based on the U.S. Youth Risk Behavior Surveillance System found that PA was associated with a reduced probability of depressive symptoms among adolescents [14]. Prospective cohort studies from China have further demonstrated that both moderate- and vigorous-intensity PA are significantly associated with lower risks of mental health problems in a non-linear dose-response manner [15]. A randomized controlled trial targeting adolescent psychiatric inpatients implemented a structured exercise intervention as an add-on therapy and confirmed that regular PA significantly alleviated depressive symptoms [16]. In each of these designs, PA is set against a depression total score: through regression in a cohort [17] or through group means in which depression was dichotomized into high and low [18]. Total depression scores treat depressive symptoms as a single outcome and cannot show whether PA is associated with how symptoms are organized [19]. If depressive symptoms sustain one another, that is the level at which an intervention would need to operate.

The network theory of mental disorders offers a fresh lens for research in this field. Mental disorder is conceptualized as a system of symptoms that mutually reinforce one another through feedback loops [20]. Grounded in this theory, network analysis reveals symptom associations and quantifies their centrality within the network structure. Estimating networks in groups differing by a modifiable behavior can reveal where symptom organization diverges, thereby highlighting central symptoms as candidate intervention targets [21]. In a network of 12 depressive symptoms and four health-risk behaviours among 22,510 older adults, inactivity was the behaviour most closely tied to depressive symptoms [22]. In 9,072 Chinese adolescents, PA behaviours and symptoms were modelled as one network, with gender rather than activity level as the contrast [23]. In these studies, PA is consistently modeled as a node within the

symptom network rather than treated as a grouping variable. A smaller set of studies has estimated networks by activity level itself. A latent profile study of 13,494 Chinese high school students described how symptom coupling shifts across four activity profiles, but did not test that shift formally [24]. A network of life satisfaction, positive and negative affect, stress, anxiety, depression and panic, estimated in adolescents and young adults, showed the same core structure across activity groups [25]. In college students, a combined 16-node anxiety–depression network was denser among the less active, and its central symptoms differed [26]. Prior dose response research on PA and adolescent depression indicates that benefits accrue around recommended levels rather than rising linearly from zero [15]. To our knowledge, this pattern has yet to be validated through network analysis.

The winter break serves as a unique period that disrupts regular routines, notably school physical education and peer contact. The structured days hypothesis posits that when the break removes the school scaffold, these behaviors rely heavily on self regulation [27]. Activity levels therefore diverge most, and are least confounded by school-level provision. Assessing students in the first days after the break thus yields a natural contrast in self-determined activity, and anchors the comparison to a period in which inactivity is both common and behaviorally meaningful. We therefore assessed students at that point, grouped them by PA level relative to the recommended threshold, and compared their depressive symptom networks. Network comparison tests (NCT) addressed three questions: (1) do the three activity groups differ in network structure, and do they differ in global strength; (2) do the ordering of central symptoms, in particular the centrality of Depressed, remain stable across PA levels; (3) if the networks are different, which symptom-symptom connections carry the difference, and in which direction.

Methods

Participants

Data were collected in March 2026, during the first two days of the new semester following the winter break. A total of 1,571 students (Grades 7–9) were initially recruited from four junior high schools in Xuzhou, Jiangsu Province, through cluster sampling with classes as the sampling units. Eligible participants were asked to complete a set of self-report questionnaires covering demographic characteristics, PA patterns during the winter break, and the 10-item Center for Epidemiologic Studies Depression Scale (CES-D10).

Participants completed the paper-and-pencil questionnaires in their regular classrooms during a designated class period. Trained research assistants supervised all sessions. Completed questionnaires were collected immediately after the session. The data from these forms were double-entered into a electronic database by two independent research assistants. Cases were excluded if they lacked informed consent, had missing responses on more than 20% of the core measure items, or exhibited clearly inattentive responses during data entry.

A total of 1,459 valid participants (mean age = 13.91 ± 0.97 years; 51.7% male) were retained for analysis. A minimum sample size of 250 participants was necessary to achieve adequate sensitivity and specificity for networks containing ≤ 20 variables [28]. Accordingly, the available sample was sufficient for the intended network analyses.

Measurements

Demographic Information

Participants provided demographic details, including gender (male or female) and school grade (Grades 7, 8, or 9).

Physical activity assessment

Participants were prompted to report their PA during the winter break by responding to three questions regarding weekly frequency (sessions), average duration per session(minutes), and typical intensity. To assess intensity, we provided three options: 1 = no sweating; 2 = light sweating; and 3 = sweating. This method, which employs exercise-induced sweating as a proxy for intensity [29] has been validated and utilized in epidemiological research [30, 31]. World Health Organization (WHO) recommend that children and adolescents aged 5–17 years should engage in an average of at least 60 minutes of moderate-to-vigorous physical activity (MVPA) per day [32]. Based on the WHO Guidelines, the sample was categorized into three groups according to their PA participation: (1) the Non-MVPA group (n = 623), comprising participants who engaged in no PA or only low-intensity activity; (2) the Insufficient MVPA group (n = 532), comprising participants who engaged in MVPA but had an average daily duration of less than 60 minutes (calculated as weekly frequency × duration per session / 7); and (3) the Sufficient MVPA group (n = 304), comprising participants who engaged in MVPA with an average daily duration of at least 60 minutes.

Depressive symptoms

Depressive symptoms were assessed using the CES-D-10 [33]. The CES-D-10 comprises 10 items: 1) I was bothered by things that usually do not bother me (Bothered); 2) I had trouble keeping my mind on what I was doing (Trouble Concentrating); 3) I felt depressed (Depressed); 4) I felt everything I did was an effort (Effort); 5) I felt hopeful about the future (Hopeful); 6) I felt fearful (Fearful); 7) My sleep was restless (Restless Sleep); 8) I was happy (Happy); 9) I felt lonely (Lonely); 10) I could not get “going” (Get Going) [34]. Students were asked to rate the frequency of symptoms they experienced in the last week on a 4-point Likert scale ranging from 0 to 3 (0 = rarely or none of the time, 1 = some or a little of the time, 2 = occasionally or a moderate amount of time, and 3 = most or all of the time). Items 5 and 8 were reverse-scored. Higher total scores indicate more pronounced depressive symptoms. The CES-D-10 retained 10 items three-factor structure from the original CES-D-20 scale [35]. This brief version

demonstrates high efficiency and good adaptability for assessing depressive symptoms in adolescents [36], and its satisfactory psychometric properties have been confirmed in Chinese adolescent samples [37]. In this study, the CES-D-10 demonstrated good internal consistency, with a Cronbach's α of 0.814. Given the skewed distribution of the total score, group differences in depressive symptom severity (CES-D-10 total score) were examined using the Kruskal–Wallis test, followed by Dunn's post-hoc tests with Benjamini–Hochberg correction.

Data analysis

Descriptive analyses, network estimation and visualization, centrality estimation, and network comparison tests were conducted using R v4.6.0.

Network estimation

We estimated a separate network for each group using the gLASSO with the EBIC model selection (gamma = 0.5). The penalty shrinks small partial correlations to zero to produce a sparse, interpretable network. Because the CES-D-10 items are ordinal (0–3 Likert-type), we used polychoric correlations as input, computed with the cor_auto function [38]. Polychoric correlations are preferable for ordinal Likert data and are widely used in recent depression network studies [39].

Centrality estimation

To identify central symptoms within the depressive network, we calculated strength and expected influence (EI) for each node using the R package qgraph [38]. Strength centrality refers to the sum of absolute edge weights connected to a given node, reflecting its direct connectivity. EI sums signed edge weights rather than absolute values, allowing positive and negative associations to be distinguished [19]. Nodes with higher centrality values were treated as more central symptoms. Centrality values were z-standardized to facilitate visual comparison across nodes.

Network accuracy and stability

We assessed network accuracy and stability with 1,000 nonparametric bootstrap resamples. Edge-weight accuracy was evaluated using 95% confidence intervals, with narrower intervals indicating higher precision. Centrality stability was quantified with correlation stability (CS) coefficients. The CS coefficient reflects the proportion of samples that can be dropped while maintaining a correlation of at least 0.70 with the original centrality order. Following prior work [39], CS > 0.50 was considered excellent, 0.25–0.50 acceptable, and < 0.25 unstable.

Network comparison Tests

To determine whether depressive networks differed by PA level, we ran NCT with 1000 permutations, following earlier recommendations. The NCT evaluates group differences at four levels: (1) network structure invariance (overall connectivity pattern), (2) global strength invariance (sum of all edge weights), (3) individual edge invariance (edge-wise differences between groups), and (4) node-level centrality invariance (strength and EI). Edge-level and centrality-level p-values were adjusted using the Benjamini-Hochberg (BH) procedure. Two-sided p-values are reported. All analyses were carried out in R v4.6.0 with the NetworkComparisonTest package [40].

Network sensitivity analyses

Because the network nodes came from Likert-type questionnaire items, normality may not hold fully. We therefore re-estimated each network using Spearman correlations, keeping the same EBICglasso procedure and tuning parameter, and re-ran the NCT with Spearman correlations.

Results

Descriptive statistics

A total of 1,459 students were included. Table 1 summarizes the demographic characteristics and comparisons across MVPA groups. The sample comprised 51.7% males and 48.3% females; Grade 7 was the largest group (38.2%), followed by Grades 8 (32.2%) and 9 (29.5%). Only 20.8% were in the Sufficient MVPA group, versus 42.7% Non-MVPA and 36.5% Insufficient MVPA. MVPA groups did not differ significantly by gender ($\chi^2 = 1.73$, $p = 0.422$) or grade ($\chi^2 = 4.20$, $p = 0.379$). Thus, physical inactivity during winter break was highly prevalent among these adolescents, with gender and grade not significant correlates. The smallest group, Sufficient MVPA (n = 304), still exceeded the previously stated minimum sample size requirement of 250.

Table 2 presents the descriptive statistics for the CES-D-10 items. Means ranged from 0.30 ± 0.59 (Get going) to 0.89 ± 0.79 (Bothered), with SDs of 0.59–0.93. All items were positively skewed (0.54–2.23), and kurtosis ranged from − 0.42 to 5.39. The total-sample floor effects ranged from 34.2% to 75.8%. The most pronounced floor effects across the Non-MVPA, Insufficient MVPA, and Sufficient MVPA groups were observed for Get going (75.8% overall; 71.9%, 80.1%, and 76.3%, respectively), Fearful (65.3%; 65.7%, 66.5%, and 62.5%), and Lonely (62.3%; 60.4%, 62.2%, and 66.4%). Given these substantial floor effects, the subsequent network analysis should be interpreted with caution.

Comparison of CES-D-10 total scores across MVPA groups are summarized in Table 3. A Kruskal–Wallis test revealed a significant difference in severity across groups ($H = 51.47$, $p < 0.001$, $\varepsilon^2 = 0.034$). Dunn's post-hoc tests showed that the Non-MVPA group scored significantly higher than both the Insufficient MVPA and Sufficient MVPA groups, whereas the latter two groups did not differ from each other.

Table 1
Demographic characteristics of the total sample and comparisons across MVPA groups

Parameter		Total (*n* = 1459)	Non-MVPA (*n* = 623)	Insufficient MVPA (*n* = 532)	Sufficient MVPA (*n* = 304)	P-Value
Gender (□, %)	Male	754 (51.7%)	314 (50.4%)	273 (51.3%)	167 (54.9%)	χ^2=1.73, p = 0.422
	Female	705 (48.3%)	309 (49.6%)	259 (48.7%)	137 (45.1%)	
Grade (□, %)	Grade 7	558 (38.2%)	236 (37.9%)	203 (38.2%)	119 (39.1%)	χ^2=4.20, p = 0.379
	Grade 8	470 (32.2%)	187 (30.0%)	180 (33.8%)	103 (33.9%)	
	Grade 9	431 (29.5%)	200 (32.1%)	149 (28.0%)	82 (27.0%)	

Table 2
Descriptive statistics for individual CES-D-10 items

Item	M ± SD	Skewness	Kurtosis	Floor (%)			
				Total (*n* = 1459)	Non-MVPA (*n* = 623)	Insufficient MVPA (*n* = 532)	Sufficient MVPA (*n* = 304)
1 = Bothered	0.89 ± 0.79	0.54	-0.29	34.20%	29.70%	35.50%	41.10%
2 = Trouble concentrating	0.85 ± 0.86	0.7	-0.34	40.80%	32.10%	46.10%	49.70%
3 = Depressed	0.77 ± 0.82	0.87	0.1	44.10%	35.30%	49.40%	53.00%
4 = Effort	0.65 ± 0.84	1.12	0.42	54.70%	48.50%	58.30%	61.20%
5 = Hopeful (rev.)	0.88 ± 0.93	0.77	-0.42	43.20%	30.80%	50.60%	55.90%
6 = Fearful	0.46 ± 0.74	1.66	2.38	65.30%	65.70%	66.50%	62.50%
7 = Restless sleep	0.73 ± 0.92	1.08	0.16	53.10%	50.10%	56.40%	53.30%
8 = Happy (rev.)	0.85 ± 0.88	0.82	-0.11	41.20%	33.20%	44.00%	52.60%
9 = Lonely	0.50 ± 0.74	1.49	1.76	62.30%	60.40%	62.20%	66.40%
10 = Get going	0.30 ± 0.59	2.23	5.39	75.80%	71.90%	80.10%	76.30%

Note: M = mean; SD = standard deviation; Floor (%) = percentage of participants endorsing the lowest response option (0 = rarely or none of the time). Items 5 (Hopeful) and 8 (Happy) were reverse-coded.

Table 3
Depressive symptoms severity (CES-D-10 total score) across MVPA groups

Variable	Non-MVPA (*n* = 623)	Insufficient MVPA (*n* = 532)	Sufficient MVPA (*n* = 304)	H	□
Total score, M (SD)	7.92 (5.08)	6.18 (4.63)	6.06 (5.08)	51.47	< 0.001
Median (IQR)	7.00 (7.00)	5.00 (6.00)	5.00 (7.00)	—	—
Range	0–24	0–22	0–30	—	—

Note: M = mean; SD = standard deviation; IQR = interquartile range; H = Kruskal–Wallis statistic. Post-hoc Dunn's tests (Benjamini–Hochberg corrected): Non-MVPA > Insufficient MVPA (z = 6.08, p < 0.001); Non-MVPA > Sufficient MVPA (z = 5.88, p < 0.001); Insufficient MVPA vs. Sufficient MVPA (z = 0.73, p = 0.47).

Network description in MVPA groups

Network models of depressive symptoms for the three MVPA groups are presented in Fig. 1. In the Non-MVPA, Insufficient MVPA, and Sufficient MVPA groups, nonzero edges numbered 36, 36, and 40 out of 45, with global strength rising from 4.13 to 4.55 and 6.84. “Depressed” was the highest-EI node in all three networks, and its EI increased steadily with MVPA level (EI = 1.14, 1.20, and 1.41; z = 1.52, 1.89, and 2.16). The nodes following it differed by group: “Lonely” (EI = 1.03, z = 1.02) and “Effort” (EI = 0.94, z = 0.63) in the Non-MVPA group; “Effort” (EI = 1.00, z = 0.85) and “Lonely” (EI = 0.96, z = 0.68) in the Insufficient MVPA group; and “Happy(rev.)” (EI = 0.98, z = 0.49) and “Get Going” (EI = 0.96, z = 0.40) in the Sufficient MVPA group. The edge weight between “Bothered” and “Depressed” was the strongest positive association in both the Non-MVPA (w = 0.29) and Insufficient MVPA (w = 0.41) networks, whereas in the Sufficient MVPA network, the strongest positive weight shifted to the edge between “Depressed” and “Lonely” (w = 0.63). Full edge weights and centrality estimates are given in Tables S1–S2 and Fig. 2.

Network accuracy and stability

Nonparametric bootstrap 95% confidence intervals for the edge weights were sufficiently narrow, supporting the accuracy of the estimated network (Fig. S1), and bootstrap difference tests for edge weights are reported in Fig. S2. Stability of the centrality indices was assessed with the case-dropping subset bootstrap. The resulting CS-C coefficients for strength and EI were 0.67 and 0.75 in the Non-MVPA group, 0.36 and 0.59 in the Insufficient MVPA group, and 0.36 and 0.60 in the Sufficient MVPA group. These results indicate that the network centrality indices were generally stable and interpretable, with the exception of strength centrality in the two active groups, which should be treated with caution (Fig. S3).

Network comparison

The NCT showed no significant differences between the Non-MVPA and Insufficient MVPA groups in either global strength (S = 0.4196, p = 0.3237) or network structure (M = 0.1818, p = 0.5295). However, significant differences were found between the Non-MVPA and Sufficient MVPA groups in both global strength (S = 2.7126, p = 0.001) and network structure (M = 0.5027, p = 0.001). Similarly, the Insufficient MVPA and Sufficient MVPA groups showed significant differences in global strength (S = 2.2930, p = 0.005) and network structure (M = 0.5646, p = 0.001).

At the edge level (after Benjamini–Hochberg correction), eight edges differed significantly between the Non-MVPA and Sufficient MVPA groups, and seven edges differed between the Insufficient MVPA and Sufficient MVPA groups, whereas no edge differed between the Non-MVPA and Insufficient MVPA groups. Five edges showed significant differences in both comparisons involving the Sufficient MVPA group. These included the edges between “Bothered” and “Fearful” (p = 0.015 and 0.009), “Depressed” and “Lonely” (p = 0.015 and 0.009), “Fearful” and “Lonely” (p = 0.018 and 0.009), “Depressed” and “Get Going” (p = 0.015 and 0.009), and “Happy(rev.)” and “Get Going” (p = 0.019 and 0.009). The remaining significant edges were unique to specific comparisons. In the Non-MVPA versus Sufficient MVPA comparison, significant differences were found in the edges between “Bothered” and “Effort” (p = 0.018), “Effort” and “Hopeful(rev.)” (p = 0.023), and “Effort” and “Lonely” (p = 0.019). In the Insufficient MVPA versus Sufficient MVPA comparison, the edges between “Bothered” and “Depressed” (p = 0.045), and “Restless Sleep” and “Lonely” (p = 0.045) differed significantly.

At the node level, in the NCT comparing the Non-MVPA and Sufficient MVPA groups, EI (the more stable of the two indices; CS = 0.60) differed significantly for Happy(rev.) (ΔEI = − 0.447, p_BH = 0.032). Node strength also differed significantly for “Depressed”, “Effort”, “Fearful”, “Lonely”, and “Get Going” (Δ = −0.572 to − 0.836, all p_BH ≤ 0.033); however, given the moderate stability of strength in the Sufficient MVPA group (CS = 0.36 < 0.5), these strength differences should be interpreted with caution. No node-level differences survived correction for the other two pairwise comparisons (Non-MVPA vs. Insufficient MVPA and Insufficient MVPA vs. Sufficient MVPA).

Robustness

When the NCT was re-run with Spearman correlations, the network-structure difference of the Sufficient MVPA group remained significant (p = 0.001), but the global-strength difference did not (p = 0.85–0.93). Thus, the structural reorganization of the Sufficient MVPA network is robust, whereas its higher overall connectivity is polychoric-specific. Under both polychoric and Spearman correlations, "Depressed" remained the most central symptom in every group, and three edges: “Bothered” – “Fearful”, “Depressed – Lonely”, and “Happy(rev.)” – “Get going”, remained stronger in the Sufficient MVPA group. However, the elevated centrality of “Happy(rev.)” in the Sufficient MVPA group was found only under polychoric correlations. The sensitivity analysis results are summarized in Table S3.

Discussion

To our knowledge, this is the first study to compare depressive symptom networks across PA groups defined by the WHO 60 min MVPA criterion in Chinese junior high school students, specifically evaluating network structure, global strength, edge weights, and centrality. Our findings indicate that the association between PA and depressive symptoms forms a threshold effect in network structure: only the Sufficient MVPA group differed structurally from the other two groups, the edge level differences reflected a reorganization of specific connections rather than an overall strengthening of the network, and “Depressed” retained its centrality across all three groups. These results offer insight into how depressive symptoms are organized at different levels of PA during a period in which daily activity is largely self-directed rather than school-organized, and they point to specific symptom connections as candidate targets for prevention.

The 60-minute MVPA threshold

The Non-MVPA and Insufficient MVPA groups showed no significant differences in network structure. Only when adolescents met the 60 min threshold did the network structure diverge significantly, accompanied by a higher global strength under polychoric correlations, revealing a threshold pattern. This empirically observed threshold provides network level support for the WHO guidelines, which recommend accumulating at least 60 minutes of daily MVPA [32]. Dose response studies on PA and youth mental health have similarly indicated that benefits accumulate near recommended levels rather than rising linearly from zero [41]. Neurobiological studies have also suggested that regular MVPA is associated with monoaminergic modulation and hippocampal neurotrophic signaling, both of which require sustained accumulation to exert their effects [42]. Our results extend this dose response logic to symptom level interactions. At this threshold, what shifts is not just the reported level of distress, but how symptoms structurally connect to one another. Regularly completing challenging activities may build mastery and self efficacy [43], yet the routine foundation of the school day is lost during the winter break. Sufficient daily MVPA may anchor a regular daily rhythm, displace screen time, and restore peer contact that would otherwise be lost during the break. These specific benefits cannot be provided by sporadic or insufficient activity.

Notably, this structural threshold was dissociable from symptom severity. The CES-D-10 total score was significantly higher in the Non-MVPA group than in the two active groups, which did not differ from each other. While symptom severity distinguished inactivity from any PA, structural divergence specifically separated sufficient activity from insufficient activity. This dissociation demonstrates that the network rewiring cannot merely be attributed to reduced symptom burden. Consequently, it highlights the unique insights provided by network analysis.

Node centrality

Across all three groups, “Depressed” was the most central symptom, pointing to its role in the onset and maintenance of depression. It is also among the most frequently endorsed and persistent symptoms in the DSM-5 account of depression, embodying the negative affect described as feeling upset or unpleasantly engaged [44, 45]. A similarly central position for “Depressed” has been documented among

other adolescent cohorts [46], general adults [47], older adults [48], and overweight individuals [49]. From a neurobiological perspective, frontostriatal salience network expansion represents a trait like brain network topology present prior to depressive symptom onset [50]. This topology acts as a vulnerability marker, preceding the illness and persisting even after symptom remission [51]. The treatment resistant dysfunction in many subcortical regions suggests that these abnormalities serve as stable trait markers of depressive propensity, rather than transient state phenomena [52]. It is unlikely that PA interventions can eliminate this central symptom node. Instead, their benefits may arise from reconfiguring the associations between “Depressed” and other symptoms.

Compared with the Non-MVPA group, the EI of “Happy(rev.)” was higher in the Sufficient MVPA group. This difference was not reproduced under Spearman correlations and did not extend to the comparison between Insufficient and Sufficient MVPA groups, so it is treated as provisional. Physiological research confirms that exercise can enhance striatal reward sensitivity and dopaminergic transmission [53], as well as alleviate inflammation induced dopamine dysfunction [54]. Such changes could make the absence of pleasure more readily perceptible rather than deepening the affective state [55, 56]. In the other two groups, “Happy(rev.)” showed relatively weak connections with neighboring nodes, whereas in the Sufficient MVPA group it appeared only modestly less embedded in the general depressive background. If this pattern replicates, a more differentiated signal of this kind could make low positive affect a viable target for early warning and intervention, although this remains to be tested prospectively [57, 58]. This reading would also be consistent with behavioral activation accounts of exercise [59].

Differentiated rewiring of symptom connections

In the Sufficient MVPA group, the edges connecting “Lonely” to “Fearful”, “Effort”, and “Restless Sleep” weakened or reversed to negative. In contrast, both the edges connecting “Depressed” to “Lonely” and “Bothered” to “Fearful” strengthened. This indicates a structural redistribution rather than an overall increase in network density, with the total volume of connectivity remaining stable while its distribution shifted.

The dissociation at the “Lonely” node can also be explained by the evolutionary theory of loneliness. According to this theory, loneliness serves as an evolutionarily conserved social pain signal that pushes the brain into a threat surveillance state. When individuals perceive themselves as socially unprotected, they become hypervigilant to social threat, sleep more shallowly, and experience elevated stress reactivity and fatigue [60]. These three edges can be interpreted as the somatic expression of this threat response. PA is well documented to act on this somatic expression: it improves sleep continuity and quality [61], reduces feelings of fatigue [62], and lowers anxiety symptoms in stress-related disorders [63]. In contrast, this physiological expression is conceptually separable from social distress shared by loneliness and depression. Interactions in PA contexts might satisfy the need for social contact, yet a lack of emotional intimacy can intensify the perceived deficit relationship quality[64]. The experience of feeling lonely while surrounded by peers reflects a state of perceived social isolation. This state is

particularly prevalent during adolescence, a stage where identity exploration and peer relationship restructuring heighten such risks [65].

The edge connecting “Depressed” and “Get Going” remained positive in both the Non-MVPA and Insufficient MVPA groups, but shifted to negative in the Sufficient MVPA group. Behavioral activation theory provides a direct explanation for this sign reversal. The behavioral model holds that depression is maintained by a self perpetuating cycle. In this cycle, a low mood reduces engagement in rewarding activities, which diminishes positive reinforcement and deepens the low mood [66]. PA is a prototypical behavioral activation: it is a scheduled, goal-directed activity that increases contact with positive reinforcement independent of current mood state [1], and behavioral activation for depression has shown efficacy comparable to that of antidepressant medication [67]. Consequently, even during periods of low mood, MVPA can break the feedback loop between depressed affect and amotivation.

Strengths and limitations

This study has several notable strengths. It benefits from a large sample of junior high school students and focuses on the winter break, a unique window when daily routines are largely self determined. Additionally, PA levels were classified according to the WHO recommended 60 minute MVPA threshold, and network analysis was used to compare symptom structures across groups.

However, several limitations warrant mention. First, because the design is cross-sectional, causal direction between PA and depressive symptoms remains unclear, and changes in their interaction over time cannot be examined. Longitudinal data would be required to test how network structure changes across time points. Second, depressive symptoms were self-reported with the CES-D-10, responses may be affected by social desirability or recall bias. Future studies could use the full 20-item CES-D and test interventions in clinically diagnosed samples to address these issues. Third, we did not differentiate PA by modality, which may have differential associations with depressive symptoms and merits further investigation. Fourth, the robustness checks supported a differentiated-rewiring rather than a globally-tighter-network interpretation: the structural reorganization and strengthening of the negative affects and low positive affect–amotivation edges were robust across estimators, whereas the increase in global strength and elevated centrality of “Happy(rev.)” were specific to the polychoric estimator. Therefore, the "behavioral activation" explanation based on the elevated centrality of “Happy(rev.)” should be regarded as tentative.

Conclusions

This study identified a threshold pattern in junior high school students' depressive symptom networks following winter break. Specifically, only the Sufficient MVPA group differed structurally, whereas the Non-MVPA and Insufficient MVPA groups were statistically indistinguishable. The Sufficient MVPA group exhibited a specific rewiring: the “Depressed” and “Lonely” edge strengthened, the “Depressed” and “Get Going” edge reversed its sign, and “Lonely” decoupled from somatic symptoms. In all groups, “Depressed” consistently emerged as the most central depressive symptom. “Happy(rev.)” showed a

higher, though estimator-dependent, EI in the Sufficient MVPA group. The former remains a consistent intervention target, whereas the latter requires replication before drawing intervention implications. PA intervention strategies targeting these specific symptoms and connections may enhance the efficacy of depression prevention. Beyond this, our study highlights the multifaceted nature of the association between PA and depressive symptoms in adolescents. Therefore, strategies aimed at providing guidance on PA during the winter break may be beneficial for protecting their mental health.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethics approval was obtained from the Ethics Committee of Nanjing Xiaozhuang University (Ethics number: XZ2026NO.28). All the participants were explicitly informed of the need to obtain a written informed consent from their parent or legal guardian. Assent was also obtained from the minors themselves to ensure their willingness to participate. All data were anonymized prior to analysis.

Author Contribution

CF: Study design, Conceptualization, Methodology, Writing – original draft. XYW: Data curation, Conceptualization, Methodology. YC: Writing – review & editing, Investigation, Visualization. XFW: Data curation, Validation. All authors reviewed and approved the final version of the manuscript.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Steinberg L, Morris AS. Adolescent Development. Annu Rev Psychol. 2001;52:83–110. https://doi.org/10.1146/annurev.psych.52.1.83.
2. Steinberg L. Cognitive and affective development in adolescence. Trends Cogn Sci. 2005;9:69–74. https://doi.org/10.1016/j.tics.2004.12.005.
3. Lu B, Lin L, Su X. Global burden of depression or depressive symptoms in children and adolescents: A systematic review and meta-analysis. J Affect Disord. 2024;354:553–62. https://doi.org/10.1016/j.jad.2024.03.074.
4. Brody D, Hughes J. Prevalence of depression in adolescents and adults: United states, august 2021–august 2023. NCHS DATA Br. 2025. https://doi.org/10.15620/cdc/174579. :1.

5. Zhou J, Liu Y, Ma J, Feng Z, Hu J, Hu J, et al. Prevalence of depressive symptoms among children and adolescents in China: A systematic review and meta-analysis. Child Adolesc Psychiatry Ment HEALTH. 2024;18:150. https://doi.org/10.1186/s13034-024-00841-w.
6. Tinsae T, Shumet S, Takelle GM, Rtbey G, Melkam M, Andualem F, et al. The burden and its determinants of mental health distress among adolescents dwelling in africa: A systematic review and meta-analysis. Child Adolesc Psychiatry Ment HEALTH. 2024;18:90. https://doi.org/10.1186/s13034-024-00782-4.
7. Zhang K, Xu W, Jing Q, Kan C, Sun X, Wu H, et al. Temporal patterns and predictive factors of depressive disorders among adolescents and young people in asia. Psychiatry Res. 2026;359:117066. https://doi.org/10.1016/j.psychres.2026.117066.
8. Cadman T, Hughes A, Wright C, López-López JA, Morris T, Rice F, et al. The role of school enjoyment and connectedness in the association between depressive and externalising symptoms and academic attainment: Findings from a UK prospective cohort study. J Affect Disord. 2021;295:974–80. https://doi.org/10.1016/j.jad.2021.08.043.
9. Psychogiou L, Navarro MC, Orri M, Côté SM, Ahun MN. Childhood and adolescent depression symptoms and young adult mental health and psychosocial outcomes. JAMA Netw Open. 2024;7:e2425987. https://doi.org/10.1001/jamanetworkopen.2024.25987.
10. Li M, Xiao Y, Ge Y, Yan H, Li X, Yue W, et al. Functional heterogeneity in non-suicidal self-injury across psychiatric disorders: Neural and psychosocial correlates. Transl Psychiatry. 2026;16:60. https://doi.org/10.1038/s41398-025-03802-9.
11. Recchia F, Bernal JDK, Fong DY, Wong SHS, Chung P-K, Chan DKC, et al. Physical activity interventions to alleviate depressive symptoms in children and adolescents: A systematic review and meta-analysis. JAMA Pediatr. 2023;177:132. https://doi.org/10.1001/jamapediatrics.2022.5090.
12. Zhang Y, Li G, Liu C, Guan J, Zhang Y, Shi Z. Comparing the efficacy of different types of exercise for the treatment and prevention of depression in youths: A systematic review and network meta-analysis. Front Psychiatry. 2023;14:1199510. https://doi.org/10.3389/fpsyt.2023.1199510.
13. Song H, Ge S, Wang Y, Ran L, Zhang H. Aerobic exercise strategies for anxiety and depression among children and adolescents: A systematic review and meta-analysis. Front Public Health. 2025;13:1555029. https://doi.org/10.3389/fpubh.2025.1555029.
14. López-Gil JF, Solmi M, García-Hermoso A, Vancampfort D, Fabiano N, Schuch FB, et al. Twenty-four-hour movement guidelines and depressive symptoms: Association, temporal trends and moderators over a ten-year period among 45,297 US adolescents. Eur Child Adolesc Psychiatry. 2025;34:2507–20. https://doi.org/10.1007/s00787-025-02663-3.
15. Zhang Y, Wang Z, Zhang R, Wang Y, Yang J, Wang F, et al. Non-linear dose-response association between physical activity and mental health in adolescents: A prospective cohort study based on SEARCH. Int J Behav Nutr Phys Act. 2025;22:146. https://doi.org/10.1186/s12966-025-01848-y.

16. Philippot A, Dubois V, Lambrechts K, Grogna D, Robert A, Jonckheer U, et al. Impact of physical exercise on depression and anxiety in adolescent inpatients: A randomized controlled trial. J Affect Disord. 2022;301:145–53. https://doi.org/10.1016/j.jad.2022.01.011.
17. Wang X, Lei J, Li W, Liu X, Chen Z, Li Y, et al. Association of physical activity and sleep duration with depression in adolescents: A cohort study in southwest China. J Affect Disord. 2026;393:120354. https://doi.org/10.1016/j.jad.2025.120354.
18. Bai D, Wu M, Pang Y, Liu X. Gender and depression: Dual pathways influencing adolescents' physical activity and psychological wellbeing. Front Public Health. 2025;13:1663388. https://doi.org/10.3389/fpubh.2025.1663388.
19. Borsboom D, Cramer AOJ. Network analysis: An integrative approach to the structure of psychopathology. Annu Rev Clin Psychol. 2013;9:91–121. https://doi.org/10.1146/annurev-clinpsy-050212-185608.
20. Beard C, Millner AJ, Forgeard MJC, Fried EI, Hsu KJ, Treadway MT, et al. Network analysis of depression and anxiety symptom relationships in a psychiatric sample. Psychol Med. 2016;46:3359–69. https://doi.org/10.1017/S0033291716002300.
21. Borsboom D. A network theory of mental disorders. World Psychiatry. 2017;16:5–13. https://doi.org/10.1002/wps.20375.
22. McInerney AM, Deschênes SS. Physical inactivity linked to depressive symptoms in people with and without diabetes: A longitudinal network analysis of health risk behaviours and individual depressive symptoms from the survey of health, ageing and retirement in europe. J HEALTH Psychol. 2025;30:4415–33. https://doi.org/10.1177/13591053251334444.
23. Yang M, Si S, Zhang K, Xi M, Zhang W. Bridging the relationship between physical exercise and mental health in adolescents based on network analysis. PsyCh J. 2024;13:835–48. https://doi.org/10.1002/pchj.756.
24. Zhang S, Liu J, Gong J, Wu S. Latent profile analysis of physical activity and mental health among Chinese high school adolescents. Sci Rep. 2026;16:20663. https://doi.org/10.1038/s41598-026-51176-9.
25. Gan Y, Zhao Z, Mao Z-X. Network analysis of mental health among adolescents and young adults with varying levels of physical activity. J HEALTH Psychol. 2026;31:246–62. https://doi.org/10.1177/13591053251345583.
26. Liang G, Wang T, Song S, Sheng S, Zhu X. Network analysis of anxiety and depression in college students with different levels of physical activity. Sci Rep. 2026;1–27. https://doi.org/10.1038/s41598-026-58945-6.
27. Brazendale K, Beets MW, Weaver RG, Pate RR, Turner-McGrievy GM, Kaczynski AT, et al. Understanding differences between summer vs. school obesogenic behaviors of children: The structured days hypothesis. Int J Behav Nutr Phys Act. 2017;14:100. https://doi.org/10.1186/s12966-017-0555-2.

28. Constantin MA. Sample size recommendations for estimating cross-sectional network models. Tilburg University; 2018. https://doi.org/https://arno.uvt.nl/show.cgi?fid=149724
29. Washburn RA, Goldfield SRW, Smith KW, McKINLAY JB. The validity of self-reported exercise-induced sweating as a measure of physical activity. Am J Epidemiol. 1990;132:107–13. https://doi.org/10.1093/oxfordjournals.aje.a115622.
30. Alig F, Muntwyler J. Validity of self-reported exercise-induced sweating as a measure of physical activity among patients with coronary artery disease. Swiss Med Wkly. 2002;132:629–629. https://doi.org/10.4414/smw.2002.10094.
31. Lobelo F, Muth ND, Hanson S, Nemeth BA, COUNCIL ON SPORTS MEDICINE AND FITNESS, SECTION ON OBESITY, et al. Physical activity assessment and counseling in pediatric clinical settings. Pediatrics. 2020;145:e20193992. https://doi.org/10.1542/peds.2019-3992.
32. World Health Organization. WHO guidelines on physical activity and sedentary behaviour. 1st ed. Geneva: World Health Organization; 2020.
33. Andresen EM, Malmgren JA, Carter WB, Patrick DL. Screening for depression in well older adults: Evaluation of a short form of the CES-D. Am J Prev Med. 1994;10:77–84. https://doi.org/10.1016/S0749-3797(18)30622-6.
34. Lin R, Xiong Y, Wang L, Chen Y, Lin J, Du N. Dissecting depression in cardiovascular disease in middle-aged and older adults: evidence that comorbidity is associated with higher depression network strength. Psychol Res Behav Manag. 2026;19:1–14. https://doi.org/10.2147/PRBM.S604559.
35. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. Appl Psychol Meas. 1977;1:385–401. https://doi.org/10.1177/014662167700100306.
36. Bradley KL, Bagnell AL, Brannen CL. Factorial validity of the center for epidemiological studies depression 10 in adolescents. Issues Ment Health Nurs. 2010;31:408–12. https://doi.org/10.3109/01612840903484105.
37. Yang W, Xiong G, Garrido LE, Zhang JX, Wang M-C, Wang C. Factor structure and criterion validity across the full scale and ten short forms of the CES-D among Chinese adolescents. Psychol Assess. 2018;30:1186–98. https://doi.org/10.1037/pas0000559.
38. Epskamp S, Cramer AOJ, Waldorp LJ, Schmittmann VD, Borsboom D. qgraph: Network visualizations of relationships in psychometric data. J Stat Soft. 2012;48:1–18. https://doi.org/10.18637/jss.v048.i04.
39. Epskamp S, Borsboom D, Fried EI. Estimating psychological networks and their accuracy: A tutorial paper. Behav Res. 2018;50:195–212. https://doi.org/10.3758/s13428-017-0862-1.
40. Van Borkulo CD, Van Bork R, Boschloo L, Kossakowski JJ, Tio P, Schoevers RA, et al. Comparing network structures on three aspects: A permutation test. Psychol Methods. 2023;28:1273–85. https://doi.org/10.1037/met0000476.
41. Tian S, Che W, Liang Z, Qiu F, Yu Y, Wang X. The effects of exercise type and dose on depression in children and adolescents: A systematic review, network, and dose-response meta-analysis. J Affect

Disord. 2026;394:120604. https://doi.org/10.1016/j.jad.2025.120604.

42. Dishman RK, Berthoud H, Booth FW, Cotman CW, Edgerton VR, Fleshner MR, et al. Neurobiology of exercise. Obesity. 2006;14:345–56. https://doi.org/10.1038/oby.2006.46.
43. Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. Pediatrics. 2016;138:e20161642. https://doi.org/10.1542/peds.2016-1642.
44. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. Fifth Edition. American Psychiatric Association. 2013. https://doi.org/10.1176/appi.books.9780890425596
45. Chekroud SR, Gueorguieva R, Zheutlin AB, Paulus M, Krumholz HM, Krystal JH, et al. Association between physical exercise and mental health in 1·2 million individuals in the USA between 2011 and 2015: A cross-sectional study. Lancet Psychiatry. 2018;5:739–46. https://doi.org/10.1016/S2215-0366(18)30227-X.
46. Feng R, Zhang Q, Wang L, Lei J, Liu X, Chen Z, et al. Network analysis of the relationship between negative life events and depressive symptoms among adolescents: A comparison between males and females. Front Pediatr. 2025;13:1624250. https://doi.org/10.3389/fped.2025.1624250.
47. Alcalde E, Rouquette A, Wiernik E, Rigal L. How do men and women differ in their depressive symptomatology? A gendered network analysis of depressive symptoms in a french population-based cohort. J Affect Disord. 2024;353:1–10. https://doi.org/10.1016/j.jad.2024.02.064.
48. Wu Y, Cai M, Yu C. Depressive symptoms and internet use among middle-aged and older adults pre- and post-COVID-19 outbreak: A network analysis. BMC Psychol. 2025;13:797. https://doi.org/10.1186/s40359-025-03119-8.
49. Chen Y, Lin Y, Yang Q, Ye B, Gao Z, Hu D, et al. Multidimensional analysis of the association between metabolic abnormality combinations and depressive symptoms in overweight and obese populations: Cross-sectional evidence from two multinational cohorts. J Affect Disord. 2025;390:119794. https://doi.org/10.1016/j.jad.2025.119794.
50. Lynch CJ, Elbau IG, Ng T, Ayaz A, Zhu S, Wolk D, et al. Frontostriatal salience network expansion in individuals in depression. Nature. 2024;633:624–33. https://doi.org/10.1038/s41586-024-07805-2.
51. Klug M, Enneking V, Borgers T, Jacobs CM, Dohm K, Kraus A, et al. Persistence of amygdala hyperactivity to subliminal negative emotion processing in the long-term course of depression. Mol Psychiatry. 2024;29:1501–9. https://doi.org/10.1038/s41380-024-02429-4.
52. Graham J, Salimi-Khorshidi G, Hagan C, Walsh N, Goodyer I, Lennox B, et al. Meta-analytic evidence for neuroimaging models of depression: State or trait? J Affect Disord. 2013;151:423–31. https://doi.org/10.1016/j.jad.2013.07.002.
53. Greenwood BN. The role of dopamine in overcoming aversion with exercise. Brain Res. 2019;1713:102–8. https://doi.org/10.1016/j.brainres.2018.08.030.
54. Hird EJ, Slanina-Davies A, Lewis G, Hamer M, Roiser JP. From movement to motivation: A proposed framework to understand the antidepressant effect of exercise. Transl Psychiatry. 2024;14:273.

https://doi.org/10.1038/s41398-024-02922-y.

55. Brush CJ, Foti D, Bocchine AJ, Muniz KM, Gooden MJ, Spaeth AM, et al. Aerobic exercise enhances positive emotional reactivity in individuals with depressive symptoms: Evidence from neural responses to reward and emotional content. Ment Health Phys Act. 2020;19:100339. https://doi.org/10.1016/j.mhpa.2020.100339.
56. Wengrovius C, Zick S, Beltz AM, Wentz EE, Ulrich DA, Robinson LE. Relations among parent-reported physical activity and interoception in children. Physiol Behav. 2022;254:113895. https://doi.org/10.1016/j.physbeh.2022.113895.
57. McMakin DL, Olino TM, Porta G, Dietz LJ, Emslie G, Clarke G, et al. Anhedonia predicts poorer recovery among youth with selective serotonin reuptake inhibitor treatment–resistant depression. J Am Acad Child Adolesc Psychiatry. 2012;51:404–11. https://doi.org/10.1016/j.jaac.2012.01.011.
58. Vinckier F, Gourion D, Mouchabac S. Anhedonia predicts poor psychosocial functioning: Results from a large cohort of patients treated for major depressive disorder by general practitioners. Eur psychiatr. 2017;44:1–8. https://doi.org/10.1016/j.eurpsy.2017.02.485.
59. Gulley LD, Shomaker LB, Kelly NR, Chen KY, Olsen CH, Tanofsky-Kraff M, et al. Examining cognitive-behavioral therapy change mechanisms for decreasing depression, weight, and insulin resistance in adolescent girls at risk for type 2 diabetes. J Psychosom Res. 2022;157:110781. https://doi.org/10.1016/j.jpsychores.2022.110781.
60. Hawkley LC, Cacioppo JT. Loneliness matters: A theoretical and empirical review of consequences and mechanisms. ann behav med. 2010;40:218–27. https://doi.org/10.1007/s12160-010-9210-8.
61. Kredlow MA, Capozzoli MC, Hearon BA, Calkins AW, Otto MW. The effects of physical activity on sleep: A meta-analytic review. J Behav Med. 2015;38:427–49. https://doi.org/10.1007/s10865-015-9617-6.
62. Puetz TW. Physical activity and feelings of energy and fatigue: Epidemiological evidence. Sports Med. 2006;36:767–80. https://doi.org/10.2165/00007256-200636090-00004.
63. Stubbs B, Vancampfort D, Rosenbaum S, Firth J, Cosco T, Veronese N, et al. An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis. Psychiatry Res. 2017;249:102–8. https://doi.org/10.1016/j.psychres.2016.12.020.
64. Cheng H. Loneliness, rumination, and adolescent psychological crisis in China: A pilot moderated mediation study. Front Psychiatry. 2026;17:1836083. https://doi.org/10.3389/fpsyt.2026.1836083.
65. Laursen B, Hartl AC. Understanding loneliness during adolescence: Developmental changes that increase the risk of perceived social isolation. J Adolesc. 2013;36:1261–8. https://doi.org/10.1016/J.ADOLESCENCE.2013.06.003.
66. Ferster CB. A functional analysis of depression. Am Psychol. 1973;28:857–70. https://doi.org/10.1037/h0035605.
67. Dimidjian S, Hollon SD, Dobson KS, Schmaling KB, Kohlenberg RJ, Addis ME, et al. Randomized trial of behavioral activation, cognitive therapy, and antidepressant medication in the acute treatment of

adults with major depression. J Consult Clin Psychol. 2006;74:658–70. https://doi.org/10.1037/0022-006X.74.4.658.

Figures

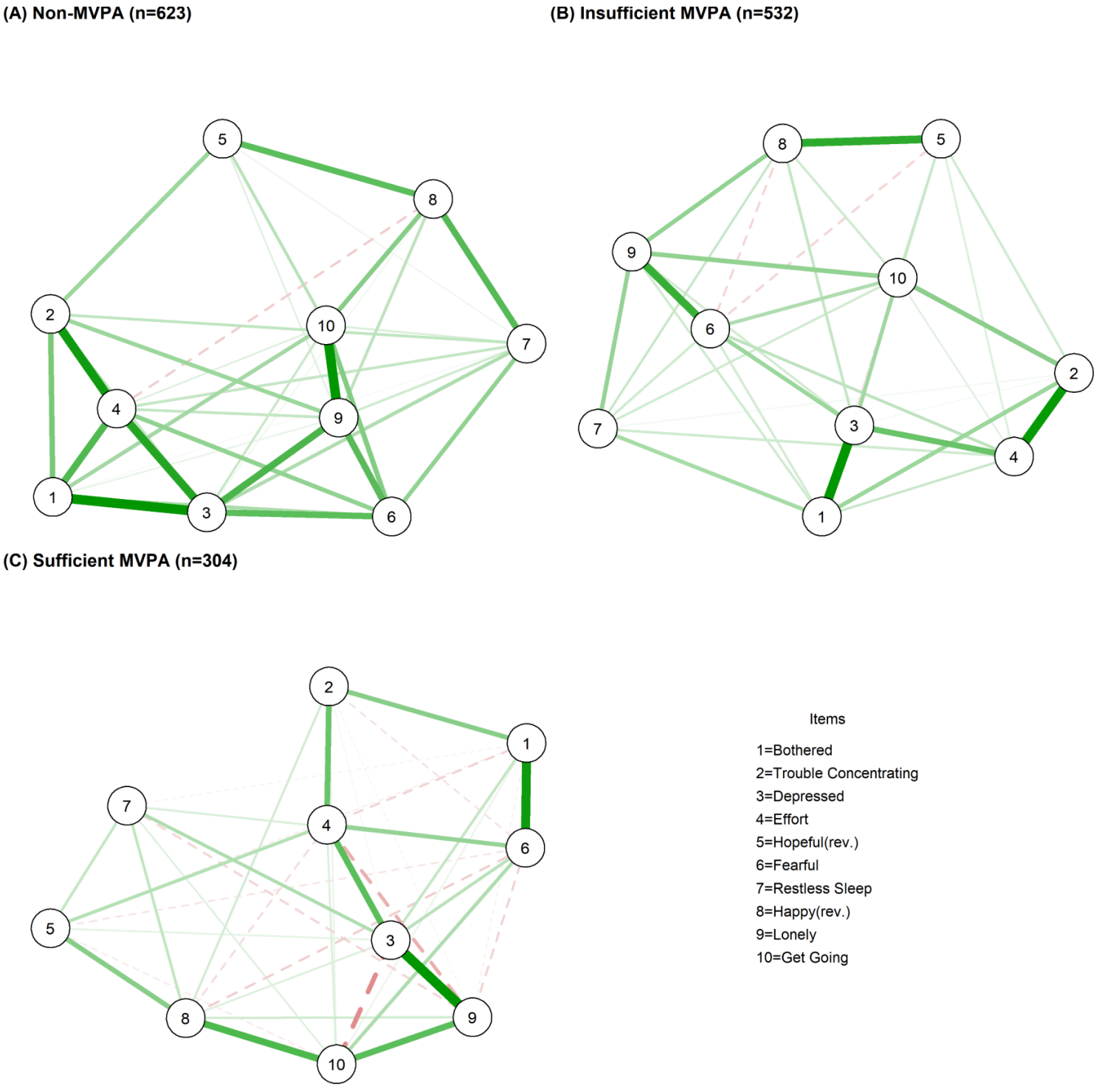

Figure 1

Network structures of depressive symptoms among MVPA groups

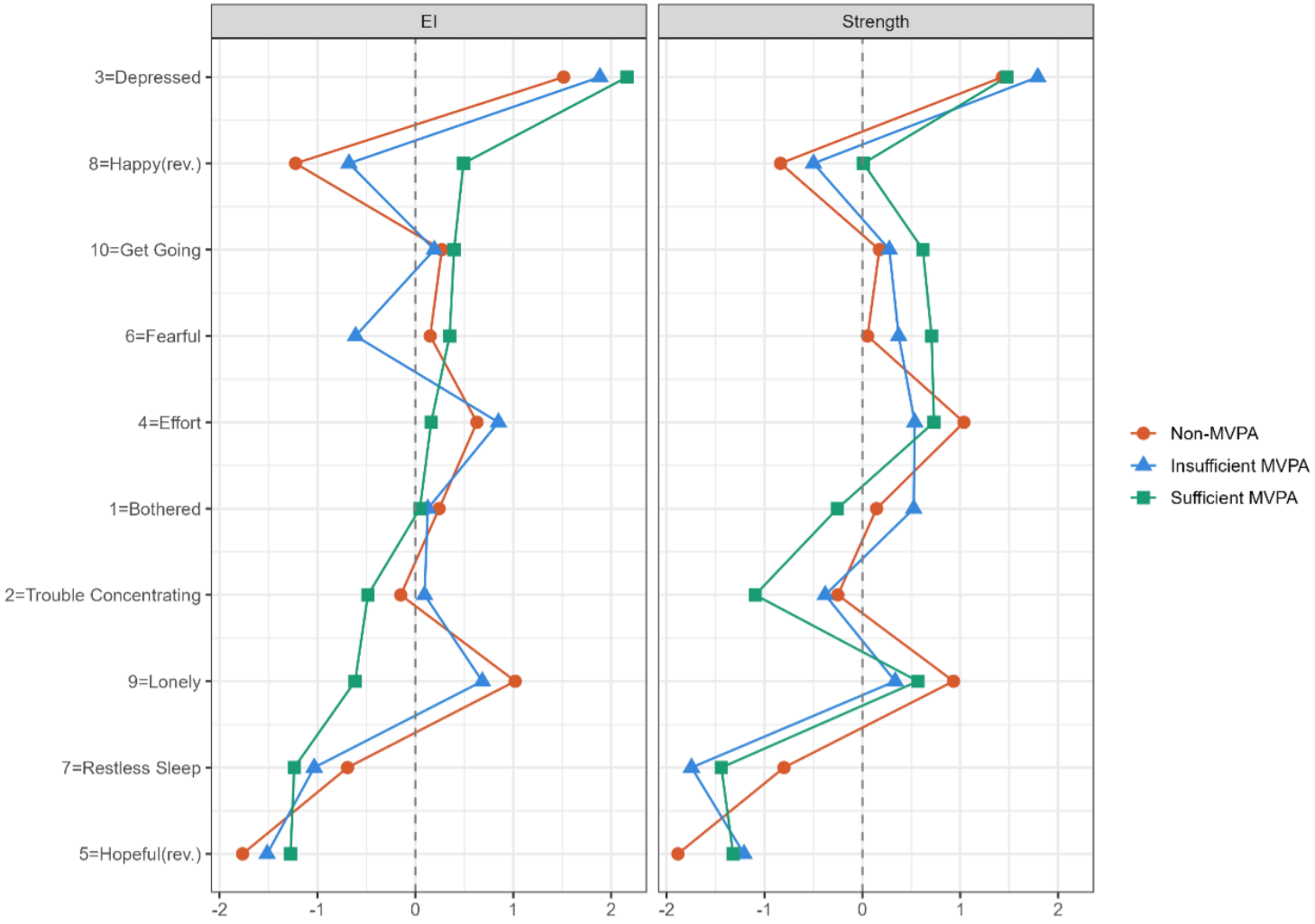

Figure 2

EI (left) and strength (right) of the ten depressive symptoms, expressed as z-scores, across the three MVPA groups.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementalAppendix.docx