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ORIGINAL ARTICLE

A Longitudinal Network Analysis of Emotion Regulation, Interpersonal Problems, and Eating Disorder Psychopathology in Chinese Adolescents

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ABSTRACT

Objective: The present longitudinal study examined sex-specific, symptom-level relationships among emotion regulation (ER), interpersonal problems (IP), and eating disorder (ED) psychopathology in a large sample of Chinese adolescents.

Method: Data were from a project with four waves of data collection ($N = 1540$; 710 boys and 830 girls) at 6-month intervals over 18 months. Questionnaires assessed ED psychopathology, ER, and IP at each wave of data collection. Longitudinal network analyses were conducted separately for boys and girls. Sex differences in the network structures were also examined.

Results: The results revealed pronounced heterogeneity in the presentation of ED psychopathology, ER, and IP across Chinese adolescent boys and girls longitudinally and intra-individually. For example, weight/shape preoccupation in ED psychopathology and awareness in ER emerged as important nodes in the temporal network for boys. However, weight/shape preoccupation and dissatisfaction in ED psychopathology were identified as the most important nodes in the temporal network for girls. Regarding bridge strength, awareness in ER emerged as the node with the highest connectivity in the temporal network for boys. At the same time, weight/shape dissatisfaction in ED psychopathology was the node with the highest connectivity for girls.

Discussion: The current study extended network theory to better understand the longitudinal interplay among ER, IP, and ED psychopathology in Chinese adolescents and their sex differences in the importance of symptoms. Such insights may pave the way for developing targeted prevention and treatment strategies for adolescent boys and girls in China.

Summary

- This study used longitudinal network analyses to examine symptom-level connections among emotion regulation, interpersonal problems, and eating disorder psychopathology in Chinese adolescents by sex.
- The results revealed several significant nodes in the network structures for boys and girls.
- Findings indicate potential intervention targets (e.g. impulse-driven eating disorder psychopathology, supporting executive functioning in emotionally charged situations) of ED symptoms in adolescents.

1 | Introduction

Eating disorders (EDs) represent a pressing global public health issue, with one of the highest mortality rates among psychiatric disorders (Arcelus et al. 2011; Klump et al. 2009; Santomauro et al. 2021; van Hoeken and Hoek 2020) and close links with poor mental and physical health outcomes (e.g., depression, anxiety, and elevated risk of suicide; Berkman et al. 2007). Thus, ongoing research is needed to elucidate the etiology of EDs. While the factors contributing to EDs are complex and varied, two theoretically-relevant constructs, ER (Brockmeyer et al. 2014; Mallorquí-Bagué et al. 2018) and interpersonal problems (IP) (Ambwani et al. 2014, 2015; Jones et al. 2015; Murphy et al. 2012), have been identified as important risk and maintenance factors for EDs.

The ER Theory of ED etiology (Lavender et al. 2015; Mallorquí-Bagué et al. 2018) suggests that disordered eating behaviors serve as maladaptive strategies to avoid or suppress negative emotions, which can result in the development of EDs. The Interpersonal Psychotherapy for EDs (IPT-ED; Murphy et al. 2012; Rieger et al. 2010) Theory is based on a model of EDs where IP, particularly those that entail negative social evaluations, contribute to ED psychopathology through a decrease in self-esteem and an increase in negative affect (Ambwani et al. 2014; Beckers, Larsen, and Burk 2023; Lampard, Byrne, and McLean 2011; Raykos, McEvoy, and Fursland 2017). A related alternative framework is the Interpersonal Emotion Regulation (IER; Zaki and Williams 2013) framework, which refers to the process by which individuals use social interactions to modulate their own or someone else's emotional experiences. The IER framework has been applied to understand interpersonal emotion management dynamics in relation to ED psychopathology (e.g., Christensen 2019; Christensen and Haynos 2020). Additionally, empirical studies found that IP and ER have each consistently been found to be significant predictors of ED psychopathology in diverse samples (e.g., Beckers, Larsen, and Burk 2023; Cooper et al. 2014; Denning et al. 2024; Lafrance Robinson et al. 2014; Lampard, Byrne, and McLean 2011). For instance, Ambwani et al. (2014) revealed that ER difficulties and IP were significant predictors of disordered eating. Also, Monteleone et al. (2023) identified binge eating, a lack of emotional clarity, nonassertiveness, and social inhibition as nodes with the highest bridge strength, indicating their pivotal roles in the symptom networks of ED psychopathology, ER, and IP.

However, existing research on ER and IP in ED psychopathology exhibits several limitations that merit further scrutiny. First, while numerous studies have examined the interrelationships between ED psychopathology and IP (e.g., Beckers, Larsen, and Burk 2023) or between ED psychopathology and emotion dysregulation (e.g., Hansson, Daukantaité, and Johnsson 2017), there is limited empirical research on the synergistic effects of emotion dysregulation and interpersonal difficulties on ED psychopathology (Monteleone et al. 2023). Second, a significant portion of extant research employs cross-sectional designs (e.g., Barnhart, Braden, and Price 2021; Beckers, Larsen, and Burk 2023; Monteleone et al. 2023; Prefit, Cândea, and Szentagotai-Tătar 2019; Raykos, McEvoy, and Fursland 2017; Zhang et al. 2022), which are unable to characterize the temporal directionality of the relationships. Moreover, although previous studies have investigated sex/gender differences in the relationships among ER, IP, and ED psychopathology (e.g., Ambwani et al. 2014; Hayaki and Free 2016; Lafrance Robinson et al. 2014; Liang et al. 2023; Striegel-Moore et al. 2009), sex differences from the longitudinal perspective need more investigation. This is an emerging field of inquiry, and to our knowledge, the present study would be the first to explore sex differences in the longitudinal relationships among ER, IP, and ED psychopathology.

1.1 | Network Analysis in ED Psychopathology

In recent years, network analysis has emerged as a methodological advancement in the study of mental disorders. The empirical application of network analysis in ED psychopathology is well-documented, encompassing clinical and nonclinical samples (e.g., Levinson, Vanzhula, and Brosof 2018; Levinson et al. 2022; Monteleone and Cascino 2021). A significant advantage of network analysis is its capacity to provide a nuanced understanding of disorders as complex systems comprising interconnected symptoms which can inform diagnostic and therapeutic strategies (Borsboom and Cramer 2013). For example, researchers can gain insight into the relative importance of each symptom within the system using centrality measures of network analysis, and network visualization enables an intuitive and comprehensive representation of the relationships among symptoms. Given those advantages, the present study employs a methodology that allows for estimating temporal effects among symptoms in longitudinal datasets (Epskamp 2020) to probe the dynamic symptom-level associations and sex differences within the context of ED psychopathology.

1.2 | The Chinese Context

EDs are common and have been an important public health issue in China. Specifically, the estimated prevalence of EDs in Chinese girls and women is similar to that in Western countries (Tong et al. 2014; Yao et al. 2021), and the prevalence of EDs for both males and females appears to be increasing over recent decades in China (Wu et al. 2022). Despite this, mechanistic research on the phenomenology of ED psychopathology in this cultural context is scarce. The current body of literature on ED psychopathology is predominantly derived from Western contexts (He et al. 2022; Ren et al. 2022; Wollenberg, Shriver, and Gates 2015). Also, unlike

most Western individualist countries, China has a collectivist culture valuing conformity to social norms and good interpersonal relations with others to support social harmony and group cohesion (Triandis 2001), both of which may foster interrelationships between ED psychopathology and IP. For example, compared to people from individualist societies, people from collectivist societies may be more likely to follow socially promoted beauty standards (e.g., thin ideals) and may be more sensitive to others' opinions of their physical appearance (Jung and Lee 2006). Adolescents, for whom the risk of ED onset is higher than that of adults, are an important population in which to study the temporal dynamics of ED psychopathology. Yet, research on Chinese adolescent samples is relatively limited.

1.3 | The Present Study

To address the aforementioned research gaps, our overall aim was to investigate the complex symptom-level interconnections among ED psychopathology, difficulties in IP, and ER using longitudinal network analysis, including the examination of sex-specific longitudinal network structures (e.g., central and bridging nodes within the network structures) to identify potential sex differences in a sample of Chinese adolescents. Given the lack of empirical studies using longitudinal network analysis on this topic, our study did not provide specific hypotheses about the central or bridging nodes or related sex differences and thus was exploratory.

2 | Method

2.1 | Participants and Procedure

These data were from an 18-month longitudinal project approved by the Research Ethics Office of Hengyang Normal University (No. 20211012kyc). The project was conducted in a high school in Hengyang, Hunan Province, China. Specifically, after the researchers obtained permission from the administrative staff in the high school, four teachers responsible for courses in mental health education introduced the project to all students in 10th grade ($N = 1761$). If students agreed to participate, they were asked to bring the informed consent form back home for their custodians' further approval with a signature and bring the signed consent form back when they returned to school. Participants in each class were offered an opportunity to win a lucky draw of gifts worth around ¥100 (about $14) at each wave of data collection. Finally, 1652 students agreed to participate and provided informed consent. Four waves of data were collected in a paper-and-pencil format across 6-month intervals over 18 months (i.e., Time 1, Time 2, Time 3, and Time 4). At each wave of data collection, we adopted multiple measures to ensure data quality. First, an attention check was used in the survey (i.e., please select "strongly agree" for this item), and surveys with failure on the attention check would be removed. Second, severely incomplete surveys with fewer than 50% completed questionnaires were removed. Moreover, research assistants carefully inspected each survey's response pattern and excluded those with careless response patterns (e.g., straight-line patterns). Finally, as in prior studies using multiple waves of longitudinal data analyses (e.g., Weng et al. 2022), we only included participants who provided two or more waves of valid data, leading to a total of 1540 students included in the final analyses (i.e., a final response rate of 87.5%; 1249, 1383, 1248, and 1056 provided valid data at T1, T2, T3, and T4, respectively), with 830 (53.9%) girls and 710 (46.1%) boys. Of the total sample, baseline age ranged from 11 to 17 years, with a mean (SD) of 15.2 (0.56) years, and baseline body mass index (BMI) ranged from 14.5 to 35.0 kg/m^2, with a mean (SD) of 19.9 (2.67) kg/m^2.

2.2 | Measures

2.2.1 | Emotion Regulation

The Chinese version of the 18-item brief version of the Difficulties in Emotion Regulation Scale (DERS-18; Jiang et al. 2022; Zhao et al. 2022) was used to measure ER, which is a multifaceted construct involving components such as awareness and understanding of emotions, acceptance of emotions, ability to control impulsive behaviors, and behaving in line with desired goals when experiencing negative emotions (Gratz and Roemer 2004). The items were rated on a 5-point Likert scale from 1 (*almost never*) to 5 (*almost always*). The DERS-18 contains six subscales: *Awareness*, *Clarity*, *Goals*, *Nonacceptance*, *Impulse*, and *Strategies*. In this study, the DERS-18 subscales showed acceptable internal consistency across all four time points (subscale-level Cronbach's αs = 0.58–0.89 at Time 1, 0.69–0.90 at Time 2, 0.70–0.91 at Time 3, and 0.77–0.93 at Time 4).

2.2.2 | Interpersonal Problems

The Chinese version of the Inventory of Interpersonal Problems–Short Circumplex (IIP-SC; Wu et al. 2015) was used to measure interpersonal problems (IP), which refers to distress arising from interpersonal sources based on Sullivan's interpersonal theory and Leary's circumplex model (Leary 1958). The IIP-SC has 32 items rated on a 5-point Likert scale from 0 (*not at all*) to 4 (*extremely*) with higher values denoting greater IP. The IIP-SC includes eight dimensions of interpersonal style, including *Domineering*, *Vindictive*, *Cold*, *Avoidant*, *Non-Assertive*, *Exploitable*, *Overly Nurturant*, and *Intrusive*. In this study, the IIP-SC subscales showed acceptable internal consistency across four time points (Subscale-level Cronbach's αs = 0.63–0.80 at Time 1, 0.74–0.83 at Time 2, 0.76–0.82 at Time 3, and 0.78–0.85 at Time 4).

2.2.3 | ED Psychopathology

The Chinese version of the 12-item Short Form of the Eating Disorder Examination-Questionnaire (EDE-QS; He et al. 2021) was used to measure ED psychopathology, which captures disordered eating behaviors and attitudes and beliefs about eating and body weight/shape (Grilo 2014). The items were rated on a 4-point Likert scale from 0 (*0 days/not at all*) to 3 (*6–7 days/markedly*). Higher total scores of EDE-QS denote greater ED psychopathology. In this study, the EDE-QS had adequate internal consistency (subscale-level Cronbach's αs = 0.87–0.91 across four waves of data collection).

2.3 | Data Analyses

2.3.1 | Network Analysis

We first performed item selection to identify distinct symptoms included in the network. In this study, we used the *goldbricker* algorithm (Jones 2023) to identify distinct ED symptoms, which led to removing four EDE-QS items. Table 1 presents descriptive statistics of the 22 nodes included in the network analysis. Second, the graphical vector autoregressive (panel-lvgvar; Epskamp 2020) analysis was used for network structure estimation. Three types of networks were estimated, including temporal, contemporaneous, and between-subject networks. In the temporal network, an edge signifies the degree to which the source node at a previous time point predicts the target node at the subsequent time point, controlling for other nodes' effects on the network's target node. In contrast, the contemporaneous network estimates the partial correlations between nodes at the same time point, controlling for temporal effects. The between-subject network, on the other hand, estimates the group-level (or between-individual level) partial correlations between nodes across subjects. Nonsignificant edges were removed using the *prune* function in the *psychonetrics* package (Epskamp 2023). To gain insight into the network stability of the graphical vector auto-regression (GVAR) model, the correlation stability (CS) coefficient was used with a CS coefficient above 0.7, suggesting acceptable stability (Epskamp, Borsboom, and Fried 2018). Third, we used the *strength* statistics (Bringmann et al. 2019) to examine the central roles of symptoms and the *bridge strength* statistics to evaluate the importance of each node connecting different clusters of nodes in the network (Community 1: six ER nodes; Community 2: eight IP nodes; Community 3: eight ED psychopathology nodes). The bridge strength measures are calculated as the sum of the absolute value of all edges that exist between a node and all other nodes that are not in the same community, which can help identify nodes of intervention or targets for further prevention strategies (Borsboom 2017). According to Epskamp, Borsboom, and Fried (2018), we also estimated the bridge stability statistics using bootstrapped standard errors with lower values suggesting better stability. In this study, we calculated bridge strength using the *networktools* package (Jones 2023). All codes have been provided on the Open Science Framework (https://osf.io/7bdwg/).

2.3.2 | Sex Differences

In this study, we aimed to examine sex differences regarding their edge weights and centrality measures of networks (van Borkulo et al. 2022). We borrowed the concept from multigroup structural equation modeling for the group comparison test of global network structures and utilized the *likelihood ratio test* (LRT; e.g., Powell and Schafer 2001; Ryu and Cheong 2017; Schmitt and Kuljanin 2008). We performed the bootstrapping resampling test for the group comparison test for centrality and bridge measures (e.g., van Borkulo et al. 2022). Analyses were performed using the R packages *psychonetrics* (Epskamp 2023) and *networktools* (Jones 2023).

3 | Results

3.1 | Network Stability

As shown in Table 2, the CS analysis suggested satisfactory edge weight stability for the temporal and contemporaneous networks with *Mean*(*CS*) ranging from 0.91 to 0.92 and $p_{r<.7}$ ranging from 0.6% to 4.5%. In addition, the edge weight stability in the between-subject network was adequate with *Mean*(*CS*) ranging from 0.72 to 0.73 for both boys and girls, respectively. Furthermore, the stability of strength centrality indices was also acceptable with *Mean*(*CS*) ranging from 0.70 to 0.82 for the contemporaneous and between-subject networks. However, the strength centrality indices in the temporal network were less stable but still acceptable with *Mean*(*CS*) ranging from 0.51 to 0.56.

3.2 | Network Analysis for Boys

3.2.1 | Centrality Measures

Figures 1 and 2 depict the network structures of the temporal and contemporaneous networks. Figures S1 and S2 depict the strength centrality measures within the boys' temporal, contemporaneous, and between-subject networks. For specific values of centrality indices categorized by sex groups, see Table S1. Specifically, *weight/shape preoccupation* (*EDE-WP*) exhibited the highest InStrength (InStrength = 2.077), while *weight/shape dissatisfaction* (*EDE-WD*) exhibited the highest OutStrength (OutStrength = 1.845) in the temporal network. In addition, *domineering* (*D/C*; Strength = 1.477 in the contemporaneous network and Strength = 1.619 in the between-subject network) of IIP-SC was identified as the most influential node for the contemporaneous and the between-subject networks.

3.2.2 | Bridge Strength Measures

Figure S3 depicts the bridge strength measures within the boys' and girls' temporal, contemporaneous, and between-subject networks. For specific values of centrality indices categorized by sex groups, see Table S2, which shows that the highest bridge strength was found in *Awareness* (*Aws*) (0.238) in the temporal network for boys. Specifically, node *Awareness* connected *Binge eating episodes* (*EDE-BE*) and node *Domineering/Controlling* (*D/C*). On the other hand, *Nonacceptance* (*Nn-C*; 0.278 in the contemporaneous network and 3.963 in the between-subject network) was identified as the node with the highest connectivity in both contemporaneous and between-subject networks (see Table S2 and Figure S3).

3.3 | Network Analysis for Girls

3.3.1 | Centrality Measures

For girls (Table S1), *weight/shape preoccupation* (EDE-WP) exhibited the highest InStrength (2.048), while *weight/shape dissatisfaction* (EDE-WD) exhibited the highest OutStrength (3.853) in the temporal network. In the contemporaneous and between-subject networks, the *overly nurturant* subscale of IIP-SC (Ov-N;

TABLE 1 | Descriptive statistics for modeled variables.

Scale	Node	Description	Time 1	Time 2	Time 3	Time 4
DERS	*Awr*	Awareness	8.345 (2.687)	8.931 (2.776)	9.126 (2.802)	9.622 (2.913)
DERS	*Clr*	Clarity	6.002 (2.414)	5.866 (2.337)	5.713 (2.323)	5.77 (2.348)
DERS	*Gls*	Goals	8.663 (3.332)	7.982 (3.252)	7.649 (3.26)	7.264 (3.111)
DERS	*Nn-C*	Nonacceptance	4.901 (2.49)	5.007 (2.409)	4.923 (2.384)	5.001 (2.484)
DERS	*Imp*	Impulse	6.023 (2.655)	5.842 (2.601)	5.65 (2.579)	5.658 (2.562)
DERS	*Str*	Strategies	5.792 (2.588)	5.815 (2.467)	5.606 (2.437)	5.873 (2.475)
IIPSC	*D/C*	Domineering/Controlling	3.253 (2.351)	3.223 (2.722)	3.248 (2.776)	3.352 (2.987)
IIPSC	*V/S*	Vindictive/Self-centered	3.253 (2.737)	3.198 (2.87)	3.16 (2.99)	3.417 (3.16)
IIPSC	*C/D*	Cold/Distant	4.161 (3.19)	3.942 (3.185)	3.803 (3.191)	3.961 (3.328)
IIPSC	*SI/A*	Socially inhibited/Avoidant	5.183 (3.765)	5.081 (3.794)	4.946 (3.745)	4.818 (3.669)
IIPSC	*Nn-S*	Non-Assertive	5.648 (3.465)	5.297 (3.565)	5.22 (3.636)	5.022 (3.623)
IIPSC	*Exp*	Exploitable	5.68 (3.325)	5.317 (3.425)	5.067 (3.464)	4.876 (3.324)
IIPSC	*Ov-N*	Overly Nurturant	5.214 (3.333)	4.954 (3.469)	4.663 (3.471)	4.612 (3.452)
IIPSC	*I/N*	Intrusive/Needy	4.463 (3.249)	4.19 (3.342)	4.043 (3.357)	4.15 (3.471)
EDEQS	*EDE-WE*	Long periods without eating	0.157 (0.482)	0.223 (0.555)	0.238 (0.573)	0.233 (0.551)
EDEQS	*EDE-FP*	Food preoccupation	0.332 (0.631)	0.393 (0.653)	0.39 (0.663)	0.391 (0.656)
EDEQS	*EDE-WP*	Weight/shape preoccupation	0.323 (0.633)	0.391 (0.67)	0.386 (0.685)	0.386 (0.66)
EDEQS	*EDE-VT*	Weight/shape control by vomiting or taking laxatives	0.035 (0.243)	0.11 (0.415)	0.129 (0.441)	0.149 (0.45)
EDEQS	*EDE-CE*	Compulsive exercise	0.378 (0.743)	0.419 (0.748)	0.375 (0.712)	0.357 (0.656)
EDEQS	*EDE-LC*	Sense of losing control over eating	0.411 (0.731)	0.401 (0.683)	0.33 (0.636)	0.359 (0.634)
EDEQS	*EDE-BE*	Binge eating episode	0.487 (0.755)	0.47 (0.722)	0.442 (0.708)	0.444 (0.698)
EDEQS	*EDE-WD*	Weight/shape dissatisfaction	1.083 (0.928)	1.047 (0.913)	1.034 (0.943)	0.966 (0.909)

Abbreviations: DERS, 18-item Difficulties in Emotion Regulation Scale; IIP-SC, Inventory of Interpersonal Problems–Short Circumplex; EDE-QS, 12-item Short Form of the Eating Disorder Examination-Questionnaire.

TABLE 2 | Network stability statistics for the edge weights and node strength measures of three networks in boys and girls.

Statistic	Network	Sex	Mean (SD)	$p_{r<.7}$ (%)
Edge weights	Temporal	Boys	0.91 (0.13)	4.5%
		Girls	0.91 (0.11)	3.9%
	Contemporaneous	Boys	0.93 (0.08)	1.8%
		Girls	0.92 (0.07)	0.6%
	Between-subject	Boys	0.72 (0.41)	25.2%
		Girls	0.73 (0.42)	27.2%
Node strength	Temporal	Boys	0.56 (0.33)	62.1%
		Girls	0.51 (0.36)	64.4%
	Contemporaneous	Boys	0.80 (0.19)	19.7%
		Girls	0.82 (0.15)	20.2%
	Between-subject	Boys	0.70 (0.38)	28.8%
		Girls	0.70 (0.34)	28.6%

Note: Statistic = parameters for the network stability analysis; Mean (SD) = means and standard deviations of CS coefficient across 1000 bootstrapping repetitions; $p_{r<.7}$ (%) = proportions of correlation between observed statistics with bootstrapped statistics lower than 0.7, with a lower value suggesting better stability.

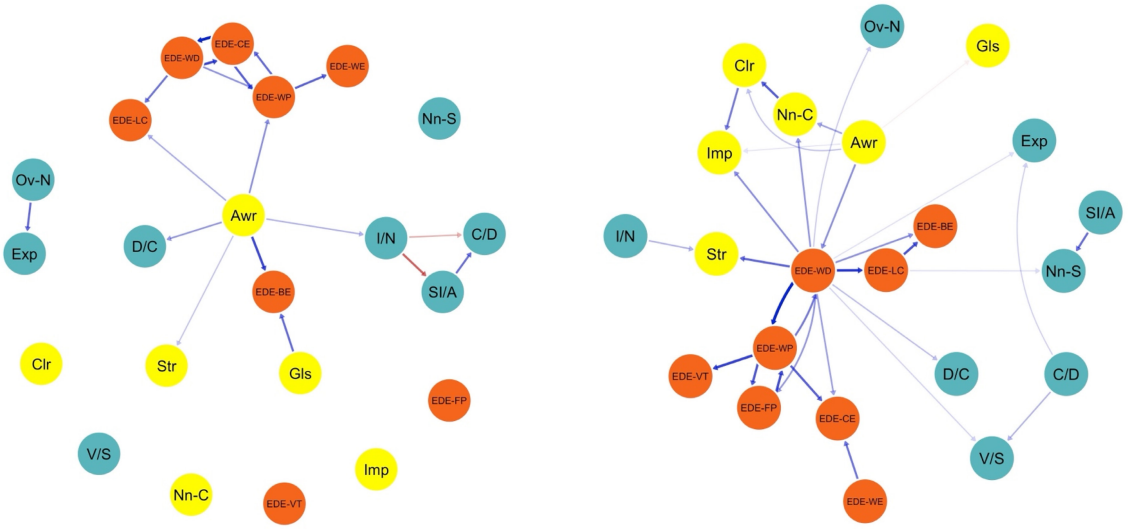

FIGURE 1 | Temporal networks for the boys (left) and the girls (right). Awr = awareness; C/D = cold/distant; Clr = clarity; D/C = domineering/controlling; EDE-BE = binge eating episode; EDE-CE = compulsive exercise; EDE-FP = food preoccupation; EDE-LC = sense of loss of control over eating; EDE-VT = weight/shape control by vomiting or taking laxatives; EDE-WP = weight/shape preoccupation; EDE-WE = long periods without eating; EDE-WD=weight/shape dissatisfaction; Exp = exploitable; Gls = goals; Imp = impulse; I/N = intrusive/needy; Nn-C = nonacceptance; Nn-S = nonassertive; Ov-N = overly nurturant; SI/A = socially inhibited/avoidant; Str = strategies; V/S = vindictive/self-centered. Nodes represent the eight EDE-QS symptoms (orange), six DERS subscales (yellow), and eight IIPS subscales (blue). The edges represent temporal effects of one node on another over time controlled for all other effects. Blue edges represent positive effects while red edges represent negative effects. The transparence of edges represents the strength of edges, with darker arrows indicating stronger edges.

1.534 and 1.420 in the contemporaneous and between-subject networks, respectively) exhibited the highest node strength.

3.3.2 | Bridge Strength Measures

For girls, *weight/shape dissatisfaction* (EDE-WD) exhibited the highest bridge strength (0.322) in the temporal network. Specifically, the bridge node connected various emotional dysregulation symptoms, such as *Strategies* (*Str*) and *Awareness* (*Awr*). *Goals* (Gls; 0.380) and *Impulse* (Imp; 3.154) in the DERS exhibited the highest connectivity in the contemporaneous and between-subject networks, respectively (see Table S2 and Figure S3).

3.4 | Sex Differences

LRTs, $\chi^2(df = 669) = 1382.74, p < 0.001$, suggested that network edge weights were unequal across boys and girls, warranting further investigation. Table 3 presents the estimated group

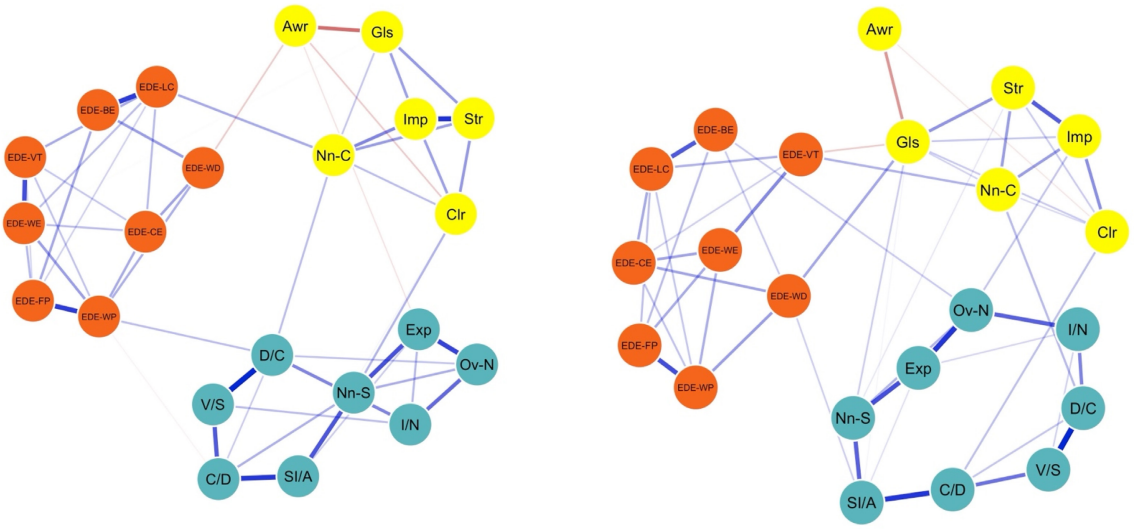

FIGURE 2 | Contemporaneous networks for boys (left) and girls (right). Awr = awareness; C/D = cold/distant; Clr = clarity; D/C = domineering/controlling; EDE-BE = binge eating episode; EDE-CE = compulsive exercise; EDE-FP = food preoccupation; EDE-LC = sense of loss of control over eating; EDE-VT = weight/shape control by vomiting or taking laxatives; EDE-WD = weight/shape dissatisfaction; EDE-WE = long periods without eating; EDE-WP = weight/shape preoccupation; Exp = exploitable; Gls = goals; Imp = impulse; I/N = intrusive/needy; Nn-C = nonacceptance; Nn-S = nonassertive; Ov-N = overly nurturant; SI/A = socially inhibited/avoidant; Str = strategies; V/S = vindictive/self-centered. Nodes represent the eight EDE-QS symptoms (orange), six DERS subscales (yellow), and eight IIPS subscales (blue). The edges represent contemporaneous associations between two nodes in the same measurement window, controlled for all other associations. Blue edges represent positive effects while red edges represent negative effects. The transparence of edges represents the strength of edges, with darker arrows indicating stronger edges.

differences in strength centrality measures. *Weight/shape control by vomiting or taking laxatives* (EDE-VT; $D = -1.186$, $p < 0.001$) had significantly lower InStrength in the boys' temporal network than in the girls' temporal network. *Long periods without eating* (EDE-WE; $D = -0.578$, $p < 0.001$) and *weight/shape preoccupation* (EDE-WP) exhibited lower OutStrength in the boys' temporal network than in the girls'.

Table 4 shows the estimated sex differences in bridge strength. Specifically, DERS *Awareness* (Awr; $D = 0.185$, $p = 0.021$) and *Goals* (Gls; $D = 0.066$, $p < 0.001$) and EDE-QS *weight/shape preoccupation* (EDE-WP; $D = 0.047$, $p < 0.001$) and *binge eating episode* (EDE-BE; $D = 0.120$, $p < 0.001$) had significantly higher bridge strength in the boys' temporal network compared to the girls'. In the contemporaneous and between-subject networks, no bridge strength measures had statistically significant sex differences. Figures S1, S2, and S3 visualize the group-specific estimates of sex differences in strength and bridge strength centrality measures. Table S2 details the sex-specific bridge statistics and their stability as indicated by bootstrapped standard errors.

4 | Discussion

In this study, we applied longitudinal network analysis to examine the temporal symptom-level connections among difficulties in ER, IP, and ED psychopathology in Chinese adolescent boys and girls. Overall, for boys, the most important bridging nodes were *awareness* and *nonacceptance* of the DERS, while *weight/shape preoccupation* and *domineering/controlling* emerged as the most central nodes. For girls, *weight/shape dissatisfaction* was identified as the most central symptom and the strongest bridging node. The analysis of sex differences revealed some significant variations between boys and girls in certain ER problems and ED psychopathology. Compensatory behaviors such as *vomiting/taking laxatives*, *food preoccupation*, and *long periods without eating* emerged as significantly more central nodes in girls than in boys. In comparison, *awareness* and *binge eating* exhibited significantly higher bridge strength in boys compared to girls.

4.1 | Central Nodes

As mentioned above, for boys, the importance of weight/shape preoccupation is supportive of the Cognitive Behavioral Therapy-Enhanced (CBT-E) model, which suggests that overevaluation of weight or shape is the central maintaining factor in EDs as the motivational driver of restrictive eating and downstream disordered eating behaviors (Fairburn 2008). The findings of bridge nodes replicate an earlier finding that emotional awareness longitudinally predicted disordered eating in adolescent girls aged 10 to 15 (Sim and Zeman 2006). For girls, the central role of the weight/shape overvaluation variables is again consistent with Fariburn's cognitive-behavioral model of EDs (Fairburn 2008).

Interestingly, unlike a previous cross-sectional study with the same topic but in a sample of adults with obesity (Monteleone et al. 2023), which pinpointed emotional dysfunction as the most influential factor, our contemporaneous network analysis revealed distinct central nodes for boys and girls, with domineering IP as the primary influencer among boys, but overly nurturant IP at the primary influencer for girls. This

TABLE 3 | Sex differences of node strength and bootstrap significant tests for the three networks.

	Temporal		Contemporaneous	Between-subject
Node	$D_{InStrength}$	$D_{OutStrength}$	$D_{strength}$	$D_{strength}$
Awr	0.306	2.324	0.934	0.778
Clr	−1.343	−0.559	0.177	0.328
Gls	0.231	0.741	−1.904	−1.028
Nn-C	−1.135	−0.669	0.292	0.532
Imp	−1.685	−0.109	0.061	−0.539
Str	−0.995	−0.109	0.437	−0.189
D/C	0.636	−0.109	0.608	0.848
V/S	−0.482	−0.109	0.079	0.665
C/D	1.990	−0.464	−0.018	0.467
SI/A	1.519	0.213	−0.626	−0.233
Nn-S	−1.030	−0.109	0.623	−0.315
Exp	1.002	−0.109	0.074	−0.256
Ov-N	−0.018	0.746	−1.165	−0.520
I/N	0.849	0.951	−0.070	−0.282
EDE-WE	1.545	**−0.578**	0.629	0.252
EDE-FP	−1.744	**−0.721**	0.000	0.126
EDE-WP	0.029	−0.584	0.791	0.263
EDE-VT	**−1.186**	−0.109	0.125	0.846
EDE-CE	−0.014	2.177	−0.653	−0.283
EDE-LC	0.403	−0.700	0.532	0.227
EDE-BE	0.791	−0.109	0.152	−0.515
EDE-WD	0.332	−2.008	−1.079	−1.172

Note: $D_{InStrength}$ = Sex differences of *InStrength* centrality measures; $D_{OutStrength}$ = Sex differences of *OutStrength* centrality measure; $D_{strength}$ = Sex differences of node strength measure. Bold numbers represent statistically significant group differences in strength measures based on the bootstrapping method.
Abbreviations: DERS, 18-item Difficulties in Emotion Regulation Scale; IIP-SC, Inventory of Interpersonal Problems–Short Circumplex; EDE-QS, Short Form of the Eating Disorder Examination-Questionnaire.

discrepancy might be attributed to the large heterogeneity of study samples (Chinese adolescents vs. Italian adults with obesity) and the different research designs used (longitudinal vs. cross-sectional).

4.2 | Bridge Nodes

The findings of bridge nodes revealed that girls and boys had different bridge symptoms maintaining the network connections of ED psychopathology and emotional and interpersonal dysfunction. The results suggested that difficulties in recognizing emotions helped to connect interpersonal difficulties with ED psychopathology for boys, consistent with the IPT-ED model centering affective, cognitive, and behavioral responses to negative social interactions in the development and maintenance of ED psychopathology. However, for girls, the results of the bridge node (*Awareness*) in the temporal network offer less support for the IPT-ED model of ED development for girls. From the perspective of empirical research, these findings further confirmed that bridge nodes differed by sex groups from the longitudinal perspective, findings that align with previous cross-sectional studies (Ambwani et al. 2014; Lafrance Robinson et al. 2014). One plausible reason is that the onset of EDs differs between boys and girls during the observed period: girls typically maintain a stable, unhealthy condition linked to weight/shape dissatisfaction, while boys start to show ED symptoms driven by emotional dysfunction. Furthermore, comparing contemporaneous networks to previous cross-sectional research, Monteleone et al. (2023) identified emotional clarity (*Clr*), nonassertive (*Nn-S*), and socially inhibited/avoidant (SI/A) as bridge nodes, findings that are inconsistent with our current findings of nonacceptance (*Nn-C*) in boys and Goals (*Gls*) in girls as key bridge nodes in the contemporaneous networks. This inconsistency suggests the single- and multi-group networks may lead to different results and highlight the need for further investigation into multiple-group longitudinal networks using diverse populations.

TABLE 4 | Sex differences of node bridge strength and bootstrap significant tests for the three networks.

	Temporal	Contemporaneous	Between-subject
Node	D_{bridge}	D_{bridge}	D_{bridge}
Awr	**0.185**	0.130	1.055
Clr	0.000	0.023	0.842
Gls	**0.066**	−0.378	−0.816
Nn-C	−0.049	−0.014	1.004
Imp	−0.053	−0.111	−0.301
Str	−0.108	−0.038	0.063
D/C	0.015	0.100	1.018
V/S	−0.018	0.000	0.698
C/D	0.000	−0.110	0.370
SI/A	0.000	−0.090	−0.060
Nn-S	−0.013	0.005	−0.047
Exp	−0.012	0.041	−0.016
Ov-N	−0.021	−0.209	−0.258
I/N	−0.003	0.000	0.077
EDE-WE	0.000	0.003	0.701
EDE-FP	0.000	0.000	0.702
EDE-WP	**0.048**	0.133	1.037
EDE-VT	0.000	−0.246	0.791
EDE-CE	0.000	0.000	0.262
EDE-LC	0.034	0.159	0.915
EDE-BE	**0.148**	−0.098	−0.314
EDE-WD	−0.322	−0.183	−0.936

Note: D_{bridge} = Sex differences of *bridge strength* centrality measures with girls as reference group. Bold numbers represent significant differences based on the bootstrapping method.
Abbreviations: Awr = awareness; C/D = cold/distant; Clr = clarity; D/C = domineering/controlling; EDE-BE = binge eating episode; EDE-CE = compulsive exercise; EDE-FP = food preoccupation; EDE-LC = sense of loss of control over eating; EDE-VT = weight/shape control by vomiting or taking laxatives; EDE-WD = weight/shape dissatisfaction.; EDE-WE = long periods without eating; EDE-WP = weight/shape preoccupation; Exp = exploitable; Gls = goals; I/N = intrusive/needy; Imp = impulse; Nn-C = nonacceptance; Nn-S = nonassertive; Ov-N = overly nurturant; SI/A = socially inhibited/avoidant; Str = strategies; V/S = vindictive/self-centered.

4.3 | Clinical Implications

Network analysis can facilitate the development of targeted interventions by highlighting symptoms strongly related to one another and/or symptoms strongly connected to other symptoms in the network (i.e., central symptoms; Borsboom 2017). The current findings underscore the importance of tailoring ED therapies to address both interpersonal dynamics and ER, particularly in the context of sex-specific patterns for adolescents. Results supported cognitive/value factors (weight/shape), emotion dysregulation, and interpersonal factors in the prediction of subsequent ED psychopathology, suggesting that a combined approach might be superior to a single treatment package in isolation, such as Fairburn's enhanced cognitive behavioral therapy, IPT-E, or dialectical behavioral therapy for ED psychopathology. Specifically, for boys, therapeutic strategies could benefit from addressing nonassertiveness and domineering/controlling behaviors, such as enhancing empathy, promoting assertiveness without aggression, and developing healthy interpersonal skills, as these are predictors of weight/shape dissatisfaction. Additionally, enhancing emotional awareness and addressing weight/shape preoccupation could be crucial given their central role in boys' networks. The findings of bridge nodes suggest that interventions for boys should focus on directly confronting emotions that are typically avoided or suppressed by ED psychopathology, employing strategies like self-monitoring to enhance awareness and recognition emotional states to facilitate dis-engagement in maladaptive behaviors (e.g., ED psychopathology).

For girls, strategies might focus more effectively on unhealthy weight/shape preoccupation and dissatisfaction, such as implementing cognitive restructuring techniques to challenge and modify distorted beliefs about body image and enhancing self-esteem through activities and therapies that emphasize personal strengths and values, beyond physical appearance. Results

suggest that intervening in girls' ED symptoms could have positive downstream effects on ER and interpersonal functioning. Additionally, a broader range of IP and ER strategies were identified in the current study as salient to girls' ED psychopathology compared to boys'. Interventions targeting impulse-driven ED psychopathology, including techniques for stimulus control and managing urges, as well as efforts to bolster executive functioning in emotionally-charged situations may be particularly beneficial for addressing girls' ED symptoms.

For boys and girls, addressing ER difficulties, such as enhancing individuals' understanding of their emotions and the ability to engage in goal-directed behaviors when experiencing negative emotions, may be key focal points in therapy. These elements have the potential to influence multiple aspects of the networks. Infusing these insights with interpersonal and ER theories and therapy practices may lead to more targeted and potentially more effective treatment approaches for EDs in adolescents. Indeed, using a quasi-experiment, Khadivizand and colleagues (2022) recommended the use of interpersonal group therapy for women with bulimia nervosa in clinical settings and confirmed the efficacy of interpersonal therapy (IPT) on depression and ER. However, it should be noted that the clinical implications in the framework of longitudinal network analysis still need more experimental evidence to confirm these speculations, especially when generalizing findings to clinical samples (e.g., patients with EDs).

4.4 | Strengths

There are several strengths to this work. First, we examined within and between-individual longitudinal networks for ED psychopathology. This approach responds to the increasing demand for research focused at the individual level (Insel, 2014) and represents a paradigm shift, moving from cross-sectional datasets to complex, dynamical systems within individuals and across subgroups. Second, we extended previous research to examine sex-specific patterns of the networks in a Chinese context. Third, our study innovatively integrates ED psychopathology, IP, and ER into one network analysis, enriching the current understanding of the dynamics of ED psychopathology.

4.5 | Limitations and Future Directions

However, this study also has limitations which represent avenues for future research. First, these data were collected retrospectively and may contain recall bias errors. Future research can apply the Ecological Momentary Assessment (EMA) as an alternative method, which allows for capturing more accurate dynamics of ED psychopathology, IP, and ER as they occur in naturalistic settings. Second, the effectiveness of intervention or treatment on central symptoms in the network analysis has not been thoroughly examined. Future investigations are warranted to assess the efficacy of interventions targeting central versus peripheral symptoms within these symptom networks. Third, another limitation concerns the source of sex-specific network heterogeneity. Whether these disparities are solely attributable to inherent group differences in characteristics or arise from a mixture of group differences and other psychosocial variables remains unresolved. Thus, to establish the causality underlying sex-specific network differences, future studies should seek to replicate these findings over an extended duration with a prospective experimental design. Additionally, a valuable future research direction would be to replicate and extend this study in Western contexts to ascertain whether the patterns observed in Chinese adolescents regarding the interplay between ER, IP, and ED psychopathology are consistent across different cultural backgrounds. This cross-cultural comparison could provide deeper insights into the universality or specificity of these relationships, informing the development of culturally-responsive therapeutic approaches.

5 | Conclusion

In summary, the present study corroborates extant network analyses, underscoring the pivotal roles of emotion dysregulation and IP in the perpetuation of ED psychopathology. There was pronounced heterogeneity in the presentation of ED psychopathology, emotion dysregulation, and IP across Chinese adolescent boys and girls longitudinally and intra-individually. Such insights may pave the way for the development of targeted prevention and treatment strategies in the Chinese context.

Author Contributions

Jihong Zhang: formal analysis, methodology, writing – original draft, writing – review and editing. **Shuqi Cui:** writing – original draft, writing – review and editing. **Hana F. Zickgraf:** writing – review and editing. **Wesley R. Barnhart:** writing – review and editing. **Yinuo Xu:** writing – original draft, writing – review and editing. **Ziyue Wang:** writing – review and editing. **Feng Ji:** writing – review and editing. **Gui Chen:** project administration, writing – review and editing. **Jinbo He:** conceptualization, data curation, funding acquisition, investigation, methodology, project administration, supervision, writing – original draft, writing – review and editing.

Disclosure

The authors have nothing to report.

Ethics Statement

These data were from the project approved by the Research Ethics Office of Hengyang Normal University (No. 20211012kyc).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

These data are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.