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ORIGINAL ARTICLE

The Connections among Problematic Usage of the Internet, Psychological Distress, and Eating Disorder Symptoms: A Longitudinal Network Analysis in Chinese Adolescents

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Abstract
With a longitudinal design, the current research examined the relationships among problematic usage of the internet (PUI), psychological distress (PD), and eating disorder (ED) symptoms in a sample of Chinese adolescents. Data were from a project with three waves of data collection ($N = 589$; aged 14 ~ 18 years at baseline) at 6-month intervals. A set of questionnaires were used to assess PUI, PD, and ED symptoms at each wave of data collection. A longitudinal network analysis was conducted. Self-induced vomiting or laxative use as an ED symptom at Time t-1 positively predicted all PUI subscales (i.e., mental withdrawal, neglect, control disorder) at Time t, while desire to lose weight as another ED symptom positively predicted all other ED symptoms. Moreover, PD might play an important role in bridging ED symptoms and PUI due to its associations with both PUI (i.e., mental withdrawal) and ED symptoms (i.e., fear of weight gain, desire to lose weight, self-induced vomiting or laxative use, and loss of control eating). The current study extended network theory to better understand the co-existence of PUI, PD, and ED symptoms in Chinese adolescents. Intervention targeting PUI, PD, desire to lose weight, and self-induced vomiting or laxative use may be effective in reducing the co-existence of PUI and ED symptoms.

Keywords Eating disorder symptoms · Problematic usage of the internet · Network analysis · Adolescents · Longitudinal · Chinese

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Eating disorders (EDs) are one of the most severe and enduring health problems (Robinson, 2009), which are associated with elevated psychological distress, higher risk of suicidality, impaired quality of life, and increased disease burden (Ágh et al., 2016; Lipson & Sonneville, 2020; Mitchison et al., 2023). To date, research on EDs is largely bound to Western countries (He et al., 2022). However, there has been evidence showing that the prevalence of EDs in some Asian countries increased rapidly (Pike & Dunne, 2015). In China, as one of the most populated countries in the world (over 1.45 billion; Worldometer, 2023), the prevalence of EDs has been found comparable to Western countries for women (Tong et al., 2014), and this prevalence has been increasing significantly in recent decades (Wu et al., 2022). In particular, the highest prevalence rates were observed in adolescent boys and girls (Wu et al., 2022). Given the detrimental outcomes and increasing prevalence of EDs in China, more studies are needed to better understand EDs in Chinese populations, especially Chinese adolescents.

EDs often co-occur with other mental health issues (Dalle Grave et al., 2021), among which is problematic usage of the internet (PUI) (Ioannidis et al., 2021). PUI, also conceptualized as problematic internet use, refers to excessive or poorly controlled urges and behaviors relating to online activities such as gaming, gambling, or social networking, which cause subjective distress and/or interference in major areas of life functioning (Fineberg et al., 2018). PUI shows high prevalence rates, ranging from 18.3% to 50.4% in adolescents (Guo et al., 2018; Xin et al., 2018), and is linked to various negative mental health outcomes such as psychological distress, loneliness, and suicidality (Cai et al., 2023). There are also empirical studies suggesting a positive association between EDs and PUI in both clinical and non-clinical samples (Claes et al., 2012; Griffiths et al., 2018; Hinojo-Lucena et al., 2019). One recent review with a meta-analysis reported that PUI was correlated significantly and positively with ED symptoms, body dissatisfaction, drive for thinness, and dietary restraint (Ioannidis et al., 2021).

Psychological distress (PD) is another mental health condition often coexisting with both EDs (Mitchison et al., 2023; Puccio et al., 2016) and PUI (Mamun et al., 2019; Wartberg et al., 2019). In this context, PD refers to a state of unpleasant feelings including negative mood, depression, anxiety, and stress (Ridner, 2004). On one hand, PD was found as a transdiagnostic risk factor of EDs in adolescents (Mitchison et al., 2023). One systematic review also reported eating pathology and depression as concurrent risk factors of each other (Puccio et al., 2016). On the other hand, PD was reported as a significant and strong predictor of PUI (Mamun et al., 2019), supporting Davis's (2001) cognitive-behavioral model of PUI in which PD was described as an important and significant predisposing factor for PUI. Hence, given that PD shows close relationships with both EDs and PUI, the presence of PD may support the association between EDs and PUI.

Previous studies have demonstrated the association between PUI and EDs, but little is known about the specific symptoms that maintain such association and their relationships with PD. This is because prior studies have mainly used latent variable models (LVM) which assume that an underlying, unobserved construct explains all observable symptoms, and thus limits our understanding of the complex, symptom-level connections of behaviors (Fried & Cramer, 2017). Specifically, both PUI and EDs consist of diverse symptoms that show different aspects of psychopathology, and using LVM may hide important, symptom-level connections (Hirota et al., 2021; Levinson et al., 2022). As complementary to LVM, the network approach treats psychological constructs as dynamic networks of symptoms, allowing for estimating direct and indirect symptom-level connections (Fried & Cramer, 2017). It assumes that comorbidities emerge from strong, inter-scale associations between bridge symptoms, and interventions targeting such bridge symptoms may meaningfully

address the co-existence of disorders (Borsboom & Cramer, 2013). Moreover, the panel network approach can distinguish between within-subject and between-subject effects, which are unachievable via cross-sectional or cross-lagged network models (Epskamp et al., 2018; Hamaker et al., 2015).

To our knowledge, no study to date has applied NA to understand the co-existence of PUI and ED symptoms. Moreover, although PUI and ED symptoms both have high prevalence among Chinese adolescents, most studies about their relationship are confined to Western contexts. However, accumulative evidence suggests cross-cultural differences in both ED symptoms (Levinson & Brosof, 2016; Miller & Pumariega, 2001) and PUI (Baloğlu et al., 2020). For instance, compared to Western countries with individualistic orientations, China has a collectivism-oriented culture that values relations with others and conformity to social norms (Triandis, 2001). Cross-cultural studies (e.g., Lee et al., 2013; Shagar et al., 2019) showed that such collectivistic characteristics might enhance the influence of pressures from others on individuals' body image, a major component or cause of EDs (Levine & Piran, 2004). Also, individualism-collectivism orientations may contribute to cultural differences in PUI (Montag et al., 2016), since individuals deviating from social norms may use the internet as a way of escaping from reality (Kardefelt-Winther, 2014). Indeed, internet "addiction" was found more prevalent in Eastern countries than in Western countries (Pan et al., 2020). Thus, due to these cultural differences, it is important to examine the relations between PUI and ED symptoms in non-Western contexts, such as China.

Therefore, based on the aforementioned discussions, to fill this research gap, the present study applied longitudinal NA in Chinese adolescents to explore both temporal and cross-sectional relationships among ED symptoms, PUI, and PD on the symptom level. To this end, the present study had two aims: (a) to identify "bridge" symptoms that connect the clusters of PUI and ED symptoms; and (b) to identify which role PD serves in the association between PUI and ED symptoms.

Method

Participants and Procedure

This study used data from a longitudinal project on body image, eating behaviors, and mental health in Chinese adolescents. Ethical approval was obtained from the Institutional Review Board of the Chinese University of Hong Kong, Shenzhen. Data were collected at a senior high school in Guangdong, China. Research assistants distributed and collected the questionnaires during class with the head teachers' assistance. Informed consent was obtained from the students and their custodians. Similar to previous longitudinal studies for ED symptoms, PUI, and/or PD (e.g., Geng et al., 2023; Mitchison et al., 2023; Tiggemann & Slater, 2017), we used a 6-month interval and collected 3 waves of data over a year timespan (i.e., T0, T1, and T2). Figure 1 shows a consort diagram of participants at each wave in this longitudinal project.

Questionnaires in a paper-and-pencil format were distributed to 842 participants involved in the project, at each wave. To ensure data quality at each wave of the data collection, our research assistants carefully inspected the paper-and-pencil surveys and removed those with one or more quality issues, including failure on attention checks, careless or problematic response patterns (e.g., straight-line and zig-zag response patterns), and severe incompletion (i.e., failing to complete 50% of the questionnaires). Finally, 600 participants

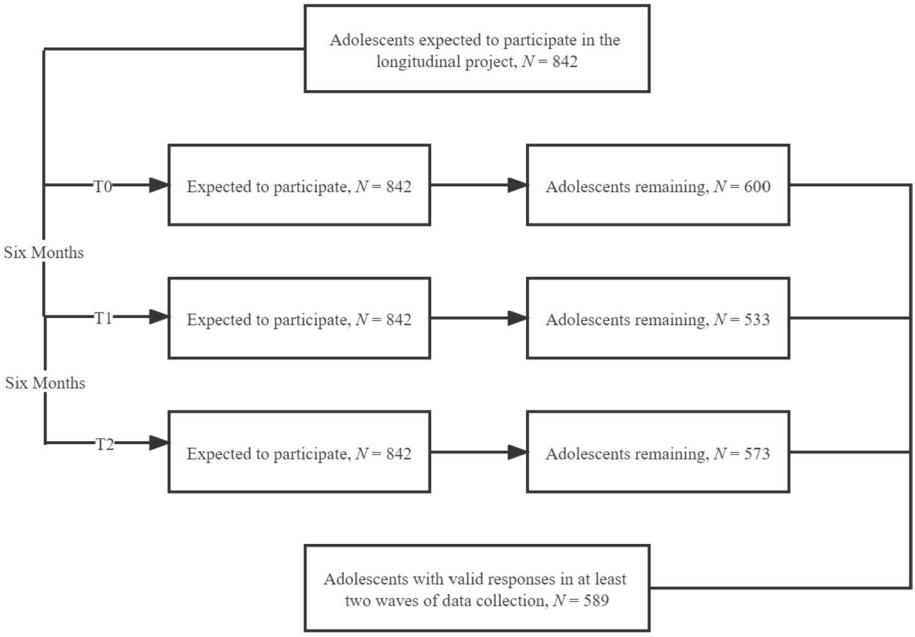

Fig. 1 Consort diagram for the number of students that participated in each wave. Reasons for remaining adolescents = passed the attention checks and completed at least 2 waves of data collection

(39.3% boys) at T0, 533 participants (38.8% boys) at T1, and 573 participants (40.5% boys) at T2 provided valid data. Following previous studies (Csajbók et al., 2023; Ren et al., 2023), only those who provided valid data in at least two waves of data collection were included for longitudinal analyses. A total of 589 (38.2% boys) participants were included in the final data analysis, with their baseline age ranging from 14 to 18 years ($M = 15.33$, $SD = 0.62$). Note that one manuscript from the same project has been published (Barnhart et al., 2023).

Measurements

Psychological Distress

PD was measured with the Chinese version of the 6-item Kessler Screening Scale (K6; Kessler et al., 2002). The items are rated on a 5-point Likert scale from 1 (none of the time) to 5 (all of the time). Higher average scores reflect higher levels of PD. The K6 scale showed good internal consistency reliability and good construct validity in Chinese adolescents (Chan & Fung, 2014). In the present study, the Cronbach's α values were 0.91 0.94, and 0.92 at T0, T1 and T2, respectively.

Eating Disorder Symptoms

The 12-item version of the Eating Disorder Examination Questionnaire (EDE-QS) measures ED symptoms (Gideon et al., 2016). The items are scored on a four-point response

scale, ranging from zero to three, with higher scores indicating higher symptom levels. The EDE-QS showed high internal consistency reliability and good convergent validity in Chinese populations (He et al., 2021). In this study, the Cronbach's α values were 0.88, 0.92 and 0.90 at T0, T1, and T2, respectively.

Problematic Usage of the Internet

The Problematic Internet Use Questionnaire Short Form (PIUQ-SF) assesses PUI (Koronczai et al., 2011). The PIUQ-SF includes nine items which are rated on a 5-point Likert scale, ranging from 1 (never) to 5 (always). The PIUQ-SF consists of three subscales: obsession (i.e., mental withdrawal symptoms such as anxiety caused by internet deprivation), neglect (i.e., neglect of everyday activities and essential needs as a consequence of internet use), and control disorder (difficulties in controlling internet use), with three items per subscale. However, obsession and mental withdrawal are indeed different concepts: obsession is a persistent preoccupation with the internet, while mental withdrawal refers to the psychological symptoms when reducing addictive behaviors (Fineberg et al., 2018). Thus, we used "mental withdrawal" to represent the obsession subscale in this study. An average score (ranging from one to five) of each subscale was used for this study; higher scores reflected higher PUI. The PIUQ-SF showed adequate internal consistency reliability and concurrent validity in Chinese samples (Koronczai et al., 2017). In this study, the Cronbach's α values were 0.87, 0.90 and 0.89 at T0, T1 and T2, respectively.

Data Analysis

All data analyses in the present study were carried out via R language version 4.1.3 (R Core Team, 2022).

Node Selection

In this study, we used the three subscales of the PIUQ-SF instead of the individual items to represent nodes in our network analysis, which ensures that each node represents a distinct entity and avoids redundancy (Fried & Cramer, 2017). Similarly, we included the total score of K6 as a single node, viewing PD as a cohesive symptom cluster. However, following prior studies (Brown et al., 2020; Chen et al., 2022; Perko et al., 2019; Sahlan et al., 2021), we included ED symptoms as nodes in networks, in order to comprehensively represent ED symptoms. Also, we assessed for node redundancy for the EDE-QS at each timepoint by using the *goldbricker* function in the *networktools* package (Jones, 2022), and the results showed no suggested reductions. In sum, we included 16 nodes (i.e., 12 ED symptoms, 3 PUI subscales, and 1 PD scale) in the network. Supplementary Table S1 presents the node abbreviations, nodes, and the items of the EDE-QS, PIUQ-SF and K6.

Network Estimation

We applied longitudinal network analysis to investigate the connections between ED symptoms, PUI, and PD nodes using a graphical vector autoregression model for panel data (*panelgvar*; Epskamp, 2020). To better interpret the connections between nodes, a regularization-based model search method was used to obtain a sparse network structure. That is, the saturated network model (i.e., a model in which all edges are included) was first

calculated, then pruned by fixing non-significant edges ($\alpha = 0.05$) to zero until the best model fit was achieved. The pruned network then removed noises and only included the most important information related to the connections among symptoms. To handle missing values (15.1% at T0, 21.2% at T1, and 17.2% at T2), as in prior literature (Epskamp, 2020; Graham, 2009), full information maximum likelihood estimation was used. This procedure generates a between-subject network that encodes partial correlations between stable means of nodes over time. It also separates within-subject correlations from between-subject correlations. As a result, it produces two networks: a temporal network encoding the temporal predictions from one node at time *t*-1 to itself or other nodes at time *t*, and a contemporaneous network encoding the remaining within-subject partial correlations between nodes, after removing temporal effects (please refer to the supplementary materials for more information about these networks). The before procedure is based on package *psychonetrics* (version 0.10; Epskamp, 2020).

Results

The current model showed acceptable fit: $\chi^2(1085) = 2180.342$; $p < 0.001$; RMSEA = 0.041; 90% CI = [0.039, 0.044], $p(\text{RMSEA} < 0.05) = 1$; CFI = 0.92, and TLI = 0.91. The full parameter matrices of the estimated temporal, contemporaneous, and between-subject networks are available in supplementary table 2. Figure 2 (left panel) shows the temporal network, which reveals the within-subject temporal predictions, standardized to partial directed correlations, between nodes. Desire to lose weight (DesLW) was the core node in the ED scale, predicting all other ED nodes positively and significantly ($p < 0.001$ for all). Higher desire to lose weight (DesLW) also predicted higher psychological distress (PD; $\beta = 0.12$, $p < 0.001$). Self-induced vomiting or laxative use (SivLax) in the ED scale was another predictor of psychological distress (PD; $\beta = 0.11$, $p < 0.001$), as well as mental withdrawal (MenWit;

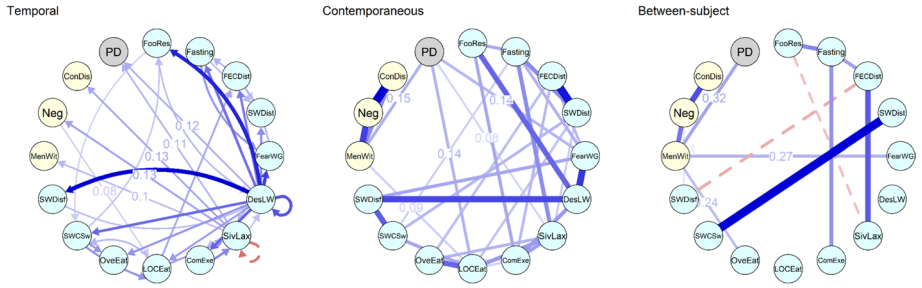

Fig. 2 The figure includes the temporal (left panel), contemporaneous (middle panel), and between-subject networks (right panel) of the model with 12 ED symptoms, 3 PUI subscale, and 1 PD scale. Blue solid edges represent positive partial correlations, while red dashed edges represent negative ones. Thicker lines represent stronger associations. The arrows in the directed network represent temporal predictions. We labeled only the edge weights of the inter-scale edges for simplicity and clarity. Light-cyan nodes represent ED symptoms: FooRes = Food Restriction, Fasting = Prolonged Fasting, FECDist = Food/Eating/Calories Distraction, SWDist = Shape/Weight Distraction, FearWG = Fear of Weight Gain, DesLW = Desire to Lose Weight, SivLax = Self-induced vomiting or Laxative use, ComExe = Compulsive Exercise, LOCEat = Loss Of Control Eating, OveEat = OverEating, SWCSw = Shape/Weight Contingency of Self-worth, SWDisf = Shape/Weight Dissatisfaction. Light-yellow nodes represent PUI subscales: MenWit = Mental Withdrawal, Neg = Neglect, ConDis = Control Disorder. The light-gray node represents Psychological Distress (PD)

$\beta = 0.10$, $p < 0.001$), neglect (Neg; $\beta = 0.13$, $p < 0.001$) and control disorder (ConDis; $\beta = 0.13$, $p < 0.001$) in the PUI scale. Moreover, neglect (Neg) in the PUI scale predicted loss of control eating (LOCEat; $\beta = 0.08$, $p = 0.002$) in the ED scale.

The contemporaneous network in Fig. 2 (middle panel) displays the average cross-sectional within-subject associations between nodes within the same time point, after controllingtemporal effects. Most edges were within the same scale. However, loss of control eating (LOCEat) in the ED scale correlated positively with mental withdrawal (MenWit; $r = 0.09$, $p < 0.001$) in the PUI scale and psychological distress (PD; $r = 0.14$, $p < 0.001$). Moreover, fear of weight gain (FearWG) and self-induced vomiting or laxative use (SivLax) in the ED scale correlated positively with psychological distress (PD; $r = 0.14$, $p < 0.001$ and $r = 0.08$, $p = 0.010$, respectively). PD also correlated positively with mental withdrawal (MenWit; $r = 0.15$, $p < 0.001$) in the PUI scale. The between-subject network in Fig. 2 (right panel) indicated that mental withdrawal (MenWit) had the most inter-scale between-subject associations. It correlated positively with psychological distress (PD; $r = 0.32$, $p < 0.001$), as well as fear of weight gain (FearWG; $r = 0.27$, $p < 0.001$) and overeating (OveEat; $r = 0.24$, $p = 0.001$) in the ED scale. Neglect (Neg) in the PUI scale was also associated with shape/weight contingency of self-worth (SWCSw; $r = 0.1$, $p < 0.001$) in the ED scale.

Discussion

With a longitudinal design, this study provides valuable insights into the symptom-level connections between PUI, ED symptoms, and PD in a non-Western context for adolescent populations. Results revealed significant connections between PD and the PUI node (i.e., mental withdrawal), as well as between PD and the ED symptoms (i.e., fear of weight gain, desire to lose weight, self-induced vomiting or laxative use, and loss of control eating). Desire to lose weight was found to predict all other ED symptoms, while self-induced vomiting or laxative use predicted all PUI nodes. Furthermore, PD might serve as a bridge between PUI and ED symptoms.

In line with previous findings (Mamun et al., 2019; Puccio et al., 2016; Wartberg et al., 2019), our study found significant associations between PD, ED symptoms, and PUI. Contemporaneous network analysis revealed positive associations between PD and three ED symptoms, namely fear of weight gain, purging (i.e., self-induced vomiting or laxative use), and loss of control eating. The temporal network showed that two ED symptoms (i.e., desire to lose weight & purging) predicted PD over time. These results support earlier research that identified PD as a key correlate of desire to lose weight (Carrard et al., 2018), fear of weight gain (Levinson et al., 2020), loss of control eating (Tanofsky-Kraff et al., 2011), and purging (Krug et al., 2022). They also suggest that these symptoms may serve as bridges between EDs and PD. Additionally, the contemporaneous network showed a stable and significant association between PD and PUI, with higher PD linked to increased mental withdrawal due to internet deprivation. However, this association was absent in the temporal network, indicating that it may occur faster than our measurement intervals (Epskamp et al., 2018). Furthermore, the between-subject network also revealed a significant role of mental withdrawal in linking both PD and ED symptoms (i.e., fear of weight gain and overeating). This underscores the importance of the relationship between mental withdrawal and psychological distress in connecting PUI, ED symptoms, and PD. Overall, the results imply that PD may act as a bridge connecting EDs and PUI, representing a shared risk factor or a maladaptive response to these disorders.

In the temporal network, two key findings emerged. First, desire to lose weight was found to predict all other ED symptoms. This corresponds to previous research suggesting desire to lose weight as a core symptom in ED symptom networks across diverse samples (Brown et al., 2020; Perko et al., 2019; Sahlan et al., 2021). Desire to lose weight was also a significant predictor of shape/weight dissatisfaction in the temporal network, and had a correlation with shape/weight dissatisfaction in the contemporaneous networks. This supports sociocultural models of ED development, which propose that thin-ideal internalization, expressed as desire to lose weight, leads to body dissatisfaction and the subsequent development of EDs (Pennesi & Wade, 2016; Sahlan et al., 2021). Second, purging (i.e., self-induced vomiting & laxative use) was found to be the core ED symptom predicting all PUI nodes. This aligns with previous findings that internet use is associated with harmful weight loss behaviors, even after controlling for body image dissatisfaction (Kwon et al., 2022; Park & Lee, 2017). Furthermore, purging may act as a bridge between PUI and EDs. This may be due to the fact that purging is often accompanied by stigma and distress (O'Connor et al., 2021; Puccio et al., 2016). To compensate for these negative emotions, individuals may turn to the internet, such as accessing pro-ED websites or social media, as a coping mechanism (Kardefelt-Winther, 2014; Yeshua-Katz & Martins, 2013; Yin et al., 2022). In all, the current findings highlight the importance of addressing two ED symptoms, desire to lose weight and purging, in the treatment of EDs and PUI.

This study is the first to apply network analysis to explore the associations between PUI, ED symptoms, and PD on the symptom level, using longitudinal analysis to highlight temporal relationships. However, there are some major limitations. First, the current study has only three measurement occasions with intervals of 6 months, limiting applicability to moment-by-moment relationships. Future studies can apply more intensive measurements to identify the relationships of PUI, PD, and ED symptoms. Second, even though gender was disproportionate in our sample (61.8% girls), we did not analyze data separately for boys and girls to explore potential gender differences in the networks due to the relatively small sample sizes for boys and girls in our study. Thus, future longitudinal studies with adequate samples for both boys and girls are needed to validate and extend our findings by exploring gender-specific networks and potential gender differences in the networks. Third, a common issue in longitudinal studies is attrition, which may result in biased estimates (Ahern & Le Brocque, 2005). This study had a relatively low rate of attrition, around 30%, lower than the typical rates of 30–70% in prior literature (Gustavson et al., 2012). Even though studies revealed that attrition rates were less likely to affect the estimates of variable associations (Gustavson et al., 2012; Saiepour et al., 2019), future research should replicate the present findings to support generalization of these findings. Finally, the use of general measures of PUI and ED symptoms in our study limited the generalizability of our findings to specific forms of PUI (e.g., problematic use of social media) in relation to ED symptoms for specific ED diagnoses (e.g., anorexia nervosa). Thus, it is important for future studies to extend our findings by using specific measures of PUI and ED symptoms in distinct clinical populations (e.g., individuals with anorexia nervosa, bulimia nervosa, binge-eating disorder).

Conclusion

In sum, this longitudinal study applied network analysis to understand the symptom-level connections between ED symptoms, PUI, and PD in Chinese adolescents. Our research suggests that PD may act as a bridge between PUI and ED symptoms, due to its associations with both PUI (i.e., mental withdrawal) and ED symptoms (i.e., fear of

weight gain, desire to lose weight, self-induced vomiting or laxative use, and loss of control eating). Additionally, we found that "desire to lose weight" predicted all other ED symptoms, while "self-induced vomiting or laxative use" predicted all PUI symptoms. Symptom-level investigations indicate that intervention on PUI subscales, PD, "desire to lose weight", and "self-induced vomiting or laxative use" may be useful in the treatment of the co-existence of ED symptoms and PUI.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11469-023-01212-w.

Author Contributions Yang Lin: Formal analysis, Writing – original draft, Writing – review & editing. Yaoxiang Ren: Investigation, Data curation, Writing – original draft, Writing – review & editing. Wesley R. Barnhart: Writing — review & editing. Tianxiang Cui: Writing — review & editing. Jihong Zhang: Writing — review & editing. Jinbo He: Conceptualization, Supervision, Funding acquisition, Investigation, Writing – original draft, Writing – review & editing. All authors approved the manuscript for submission.

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Data Availability The data used are available from the corresponding author upon reasonable request.

Declarations

Ethical Approval The ethical approval was obtained from the Institutional Review Board of the Chinese University of Hong Kong, Shenzhen (No. EF20210113001).

Informed Consent Informed consent was obtained from all the participants and their custodians.

Conflicts of Interest The authors have no conflict(s) of interest to declare.

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