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A Network Investigation of Eating Disorder Symptoms and Risk Factors Before and After a  
Prevention Program in Adolescent Girls

By

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Submitted in partial fulfillment of the requirements for  
Graduation *summa cum laude*  
and  
for Graduation with Honors from the Department of Psychological and Brain Sciences

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### Abstract

Eating disorders (EDs) are psychological disorders characterized by disturbances in eating that commonly develop during adolescence and may be influenced by risk factors, both ED-specific (i.e., factors linked to future ED symptoms) and transdiagnostic (i.e., factors underlying multiple psychological disorders). Network analysis allows for the study of the connections between ED symptoms and risk factors by identifying central symptoms (i.e., the most interconnected symptoms) and bridge symptoms (i.e., symptoms which strongly connect across the symptom and risk factor clusters). Examining networks of ED symptoms and risk factors in adolescence can inform how risk factors influence ED development, as well as how this can be disrupted by prevention programs. The current study ( $N=301$  adolescents) used network analysis to estimate the unique connections across ED symptoms, ED-specific risk factors (feared concerns about eating, food avoidance behaviors, eating anxiety, thinness and restricting expectancies, and exercise dependence), and transdiagnostic risk factors (emotion dysregulation, maladaptive perfectionism, social appearance anxiety, and negative urgency) in adolescent girls before and after an ED prevention program. The most central symptom in both networks was *feared concerns about eating*. The most central bridge symptoms in the pre-network were *thinness/restricting expectancies* and *feared concerns about eating*. The most central bridge symptom in the post-network was *thinness/restricting expectancies*. A network comparison test revealed twenty significantly different edges. These findings suggest that prevention programs targeting central risk factors (e.g., feared concerns about eating) and bridge risk factors (e.g., thinness/restricting expectancies) may limit the escalation of risk factors to full-threshold EDs in adolescents. Understanding ED risk factors specific to adolescents can result in better prevention programs optimized to reduce incidence and address the heterogeneity of EDs.

### **Lay Summary**

Eating disorders (EDs) are psychological disorders that present with disordered eating behaviors, including binge eating, restricting, and purging, and cognitive dysfunction, such as distorted thoughts about food and body image. EDs can lead to poor health and social outcomes, suicidal ideation, and in the most severe circumstances, death. EDs often emerge during adolescence. Research has identified certain risk factors that may contribute to the development of EDs during this critical period. Such risk factors can be specific to EDs, in that they underlie ED development, or transdiagnostic, in that they underlie many psychological disorders, like depression and anxiety, as well as EDs. Due to the high rate of EDs among adolescents, prevention programs like the Body Project have been developed to reduce ED occurrence.

The current study aimed to compare ED symptoms and risk factors before and after the Body Project using network analysis. Network analysis is a statistical technique that identifies the most interconnected symptoms (i.e., symptoms that are strongly connected and drive the relationship between one another) and the symptoms that are most highly connected across risk factors and ED symptoms. Our results found that thinness/restricting expectancies (i.e., expecting that thinness or food restriction will make oneself better) and feared concerns about eating (i.e., fears about the consequences of eating) were the most highly interconnected symptoms across risk factors and ED symptoms. This may suggest that these risk factors are especially important in the development of EDs in adolescents. Targeting thinness/restricting expectancies and feared concerns about eating may improve prevention programs for EDs. Improved prevention programs targeting symptoms that are driving ED development will reduce the incidence of EDs and result in better outcomes.

## **A Network Investigation of Eating Disorder Symptoms and Risk Factors Before and After a Prevention Program in Adolescent Girls**

Eating disorders are psychological disorders characterized by disturbances in eating behaviors (e.g., fasting, binge eating), which can result in poor health outcomes, impairment, and mortality (Crow et al., 2009; Rome & Ammerman, 2003). Eating disorders commonly emerge during mid-to-late adolescence, between the ages 16 and 20, and are highly prevalent, particularly among young women, with prevalence rates as high as 15% among this age group (Allen et al., 2013; Stice et al., 2009). In addition to the high occurrence of eating disorders among adolescents, many within this age group who meet criteria for eating disorders present with comorbid disorders, like depression, anxiety disorders, and obsessive-compulsive disorder (Mohammadi et al., 2020). Those with eating disorders and comorbid disorders also report more severe impairment on their lives, specifically social impairment, as well as heightened levels of suicidal ideation and attempts, suggesting that eating disorders are severe mental illnesses that are important to study in this age group (Swanson et al., 2011).

The emergence of eating disorders during adolescence may be a result of certain risk factors (i.e., variables that have been found to predict a subsequent pathological outcome prospectively), both eating disorder-specific (i.e., risks factors that have been found to prospectively predict eating disorder symptoms) and transdiagnostic (i.e., risk factors that underlie multiple psychological disorders) (Nolen-Hoeksema & Watkins, 2011; Stice, 2002). The high incidence, prevalence, and impairment of eating disorders among adolescents demonstrates the need for more research examining the connections across risk factors and eating disorder development in this population.

### **Eating Disorder-Specific Risk Factors**

The development and maintenance of eating disorders may be influenced by many different psychological risk factors that occur in adolescence (Rohde et al., 2015; Stice et al., 2017). These risk factors include eating disorder-specific vulnerabilities, such as fear of food, thinness and restricting expectancies, and exercise dependence. Fear of food (i.e., maladaptive affective response to food, characterized by anxiety, avoidant behaviors, and maladaptive thoughts around eating and food) has been linked to higher body dissatisfaction and eating concerns among an adolescent sample (Levinson & Byrne, 2015; McNamara et al., 2008). Previous studies have also found that women with abnormal eating attitudes were more likely to report having a fear towards foods (Harvey et al., 2002). Beyond common fears of eating disorder-related stimuli, expectancies related to these stimuli may also play a role. Specifically, the role of thinness and restricting expectancies (i.e., expecting that thinness or food restriction will make oneself or one's life better) have been shown to play a part in the development of eating disorders in an adolescent sample (Annus et al., 2008). Alongside these expectancies, the engagement in certain behaviors, like excessive exercise (i.e., physical activity that becomes compulsive and is accompanied by cognitive problems like withdrawal and lack of control, among others), may contribute to eating disorder risk (Brososof et al., 2020). Research has found that compulsive exercise and exercise dependence may contribute to more severe and lasting eating disorder pathology (Meyer et al., 2011). Examining exercise as a risk factor during adolescence is especially important because longitudinal research has shown that desire to be leaner to improve performance in sports among adolescents was predictive of disordered eating (Krentz & Warschburger, 2013). Studying how eating disorder-specific risk factors contribute to subsequent eating disorder development in adolescents is crucial for informing prevention efforts among this age group.

### **Transdiagnostic Risk Factors**

In addition to these eating disorder-specific risk factors, there are many transdiagnostic risk factors that have been found to contribute to the development of eating disorders and other comorbid disorders (e.g., depression, anxiety) in adolescents. Transdiagnostic risk factors include emotion dysregulation, maladaptive perfectionism, social appearance anxiety, and negative urgency, to name a few. For example, emotion dysregulation (i.e., the inability to identify, manage, and regulate emotions) predicted increases in eating pathology, anxiety symptoms, and aggressive behavior in adolescents over a four year span (McLaughlin et al., 2011). Perfectionism (i.e., excessively high personal standards accompanied with extreme concern over perceived failures) among adolescents was correlated with distorted eating attitudes two years later (Westerberg et al., 2008). Additionally, social appearance anxiety (i.e., the fear of being negatively evaluated due to one's appearance) predicted eating disorder symptoms and social anxiety disorder symptoms within an undergraduate sample (Hart et al., 2008; Levinson & Rodebaugh, 2012). Recent work has identified a unique, prospective relationship between social appearance anxiety and eating disorder symptoms in adolescents as well (Christian, Ngo, et al., 2020). Negative urgency (i.e., tendency to act rashly when experiencing negative affect) is the facet of impulsivity most linked to eating pathology and other psychiatric symptoms (Bardone-Cone et al., 2016). A prospective study on negative urgency and eating disorder behaviors in university women found that increased negative urgency predicted later eating disorder behaviors (Fischer et al., 2012). Transdiagnostic risk factors pose serious risk for eating disorder development and understanding their relation to eating disorder symptoms during the critical period of adolescence may contribute to improved outcomes for these individuals, such that

prevention targeting these risk factors could help prevent eating disorders and other comorbid disorders.

### **Network Analysis in Eating Disorders**

Understanding how psychological risk factors in adolescents are related to each other and to eating disorder symptoms across time has been an important question that has long plagued the eating disorder field. This understanding is crucial for the prevention of eating disorders among adolescents specifically, because eating disorders most commonly emerge during this developmental period (Allen et al., 2013; Stice et al., 2017). Previous research has examined eating disorder symptoms and risk factors in adolescent populations, but few have studied multiple, interacting risk factors within the same model, and even fewer have examined the connections to specific eating disorder symptoms (e.g., fasting; feeling fat; as opposed to global eating disorder symptoms) (Stice et al., 2017; Stice, Marti, et al., 2011). One way to conceptualize the relationship between eating disorder symptoms and risk factors is network theory. Network analysis is a statistical technique based on network theory, which posits that psychological disorders are driven by the dynamic interactions of the symptoms underlying the disorder which perpetuate one another (Levinson, Vanzhula, et al., 2018; McNally, 2016). In the current study, network analysis allows for the visualization of important connections among specific eating disorder symptoms and risk factors (Levinson, Vanzhula, et al., 2018). Network analysis can identify central symptoms (i.e., symptoms which are strongly interconnected) and bridge symptoms (i.e., symptoms which strongly connect across two different symptom clusters) within a network.

In the current study, central symptoms are the symptoms and risk factors that emerge as the most highly connected and influential to all others within the network, while bridge



symptoms are the specific symptoms that connect across eating disorder symptoms and risk factors, which theoretically drive the relationship between risk factors and subsequent symptoms (McNally, 2016). Several studies have used network analysis to examine eating disorder symptoms in adolescents and have reported that overvaluation of shape and weight emerged as central symptoms, which is consistent with previous eating disorder network research (Calugi et al., 2020; Levinson, Vanzhula, et al., 2020). Network analysis research among adolescents has focused heavily on anorexia nervosa and to date, no studies have looked at how specific eating disorder symptoms and risk factors relate to one another longitudinally using network analysis (Christian, Perko, et al., 2020; Monteleone et al., 2019). This question is especially important to test in an adolescent sample, as eating disorders frequently develop from risk factors across this critical period (Nolen-Hoeksema & Watkins, 2011; Rohde et al., 2015).

### **Network Analysis Across an Eating Disorder Prevention Program**

In response to the high risk of eating disorder development among adolescents, prevention programs have been developed in an attempt to mitigate the incidence and the negative impact of eating disorders. One such prevention program is the Body Project, an eating disorder prevention program that combats the thin ideal or the “appearance ideal” through methods of speaking, writing, and taking action (Stice et al., 2008). The effectiveness of this program has been studied and shown to decrease transdiagnostic risk factors at one month follow up and eating disorder symptoms at three year follow up in high school samples (Christian et al., 2019; Stice, Rohde, et al., 2011). Although research suggests the Body Project is efficacious in decreasing some symptoms and risk factors prospectively, no research has examined eating disorder networks across two time points, before and after the implementation of the Body Project, to examine if the intervention may influence the network structure of symptoms.

Examining networks of eating disorder symptoms and risk factors before and after a prevention program can elucidate whether the eating disorder prevention program has an impact on the unique relationships across risk factors and eating disorder symptoms, which can provide insight into whether the prevention program is effectively targeting these associations. This study expanded on previous work that has tested the effectiveness of change in symptom severity during the program to examine if network structure also changes or whether the networks remain unchanged after the Body Project (Stice et al., 2008). The ability of the prevention program to disrupt connections between risk factors and symptoms is important to consider in testing the efficacy of the program and when thinking about future strategies to prevent eating disorders.

### **Current Study**

The current study used network analysis to examine connections across eating disorder symptoms, eating disorder-specific risk factors (feared concerns about eating, food avoidance behaviors, eating anxiety, thinness and restricting expectancies, and exercise dependence), and transdiagnostic risk factors (emotion dysregulation, maladaptive perfectionism, social appearance anxiety, and negative urgency) at two different time points across a four-week span: pre- and post- Body Project. Central symptoms, bridge symptoms, and edges connecting across eating disorder symptoms and the two clusters of risk factors were identified. A network comparison test (NCT) and examination of central and bridge symptoms was used to identify if there are differences before and after the intervention. I hypothesized that there would be strong connections between both eating disorder-specific risk factors and transdiagnostic risk factors to eating disorder symptoms at baseline, but that the connections would be stronger between eating disorder symptoms and eating disorder-specific risk factors compared to eating disorder symptoms and transdiagnostic risk factors. Next, I hypothesized that there would be fewer and

weaker bridge symptom connections after completion of the Body Project, compared to before, suggesting the prevention program is disrupting these reinforcing connections. I predicted that there would be significantly larger pre-post change in connections between eating disorder-specific risk factors and eating disorder symptoms than with transdiagnostic risk factors. My final hypothesis was exploratory, in that I hypothesized that the NCT would reveal differences pre- and post-Body Project but did not make any explicit predictions as to the exact nature of these changes. This hypothesis was exploratory because many complex relations exist within a network and no prior research has tested differences in edges between two networks across an intervention program using a NCT.

## **Method**

### **Participants**

Participants were 301 female adolescents from two private, all-female high schools. Participants were recruited as a part of a study examining the implementation of the Body Project. Participants completed a battery of surveys at baseline and one week after completion of the Body Project. The current study used initial and final surveys collected from this study to test the current hypotheses. Participants primarily identified as white ( $n = 254$ , 84.4%) and ranged from 14-17 years of age (see Table 1 for additional demographic information).

### **Procedure**

Procedures were approved by the University of Louisville Institutional Review Board. Participants were recruited through their high schools to participate in the Body Project program. Informed consent was obtained from parents through an informed consent form and assent was obtained from the students. The program consisted of four sessions spanning four weeks, facilitated by volunteers, and took place during regularly scheduled health courses.

Questionnaires were also sent out and completed prior to the start of the program, immediately following completion of the program, and at 1-month follow-up via RedCap (Harris et al., 2009). The pre- and post-surveys are used for the current project. After all questionnaires were completed, participants were debriefed. For more information regarding the implementation of the Body Project in the current sample, see (Christian et al., 2019).

## Measures

*Eating Disorder Examination-Questionnaire (EDE-Q;* Fairburn & Bèglin, 1994). The EDE-Q is a 41-item measure that uses a seven-point Likert scale to assess eating disorder attitudes and beliefs in the past 28 days. Items were selected for the network using item selection to determine the most central symptoms. The EDE-Q has shown validity, reliability, and acceptable to excellent internal consistency among several age groups, including adolescents (Isomaa et al., 2016).

*Fear of Food Measure (FOFM;* Levinson & Byrne, 2015). The FOFM is a 25-item self-report measure that is rated on a seven-point Likert scale and measures cognitive and behavioral outcomes related to the fear of food. The current study used the three FOFM subscales: Anxiety About Eating, Food Anxiety Behaviors, Feared Concerns. The FOFM has shown good psychometric properties among undergraduate and community samples (Levinson & Byrne, 2015).

*Exercise Dependence Scale-Revised (EDS-R;* Hausenblas & Downs, 2002). The EDS-R is a 21-item measure that is rated on a six-point Likert scale and measures excessive exercise. The EDS-R total score was used within the networks to examine excessive exercise. The EDS-R has shown good reliability and validity in an undergraduate sample (Downs et al., 2004).

***Thinness and Restricting Expectancies Inventory (TREI;*** Hohlstein et al., 1998). The TREI is a 44-item self-report questionnaire, rated on a seven-point Likert scale, that measures an individual's expected benefits of thinness and dieting. The current study used the total score for the TREI. The TREI showed good reliability and validity among an adolescent population (Simmons et al., 2002).

***Frost Multidimensional Perfectionism Scale (FMPS;*** Frost et al., 1990). The FMPS is a 35-item self report measure, rated on a five-point Likert scale, that examines an individual's desire to achieve high-performance standards and the tendency to be overly critical of one's performance. The FMPS contains six subscales, however the current study focused on maladaptive perfectionism, which includes summing the following subscales: Concern Over Mistakes, Doubts About Actions, Parental Criticisms, and Parental Expectations. The FMPS has shown good internal consistency and test-retest reliability among children and adolescents (Gavino et al., 2019).

***Social Appearance Anxiety Scale (SAAS;*** Hart et al., 2008). The SAAS is a 16-item measure, rated on a five-point Likert scale, that assesses one's anxiety around being negatively evaluated by others due to appearance, including body shape. This study used the total score for the SAAS. The SAAS has demonstrated high internal consistency, test-retest reliability, and discrimination among adolescent populations (Dakanalis et al., 2016).

***State Difficulties in Emotion Regulation Scale (S-DERS;*** Lavender et al., 2017). The S-DERS is a 21-item measure that examines state emotion regulation using a five-point Likert scale. The S-DERS has four subscales, but the current study used the total S-DERS score to measure state emotion regulation within the two networks. The S-DERS showed internal

consistency and construct validity for the total scale and subscales among a community sample of young adult women (Lavender et al., 2017).

*Urgency, Premeditation, Perseverance, and Sensation Seeking Impulsive Behavior Scale (UPPS-P;* Lynam et al., 2007). The UPPS-P is a 59-item self report measure that assesses features of impulsive behavior and is rated on a four-point Likert scale. It contains five factors, but this study only used the factor Negative Urgency. The UPPS-P has shown adequate psychometric properties among a college sample (Pilatti et al., 2015).

### **Data Analytic Procedure**

Missing data was estimated using multiple imputation through Multivariate Imputation by Chained Equations (MICE) package in R (Buuren & Groothuis-Oudshoorn, 2010). 5.2% of the pre-Body Project data and 10.9% of the post-Body Project data were missing.

Two networks were modeled, the first using data from baseline, before the Body Project and the second using data collected after completion of the Body Project. In both the pre- and post-Body Project networks, we included five nodes representing total scores and subscales of common eating disorder-specific risk factors (feared concerns about eating, food avoidance behaviors, eating anxiety, thinness and restricting expectancies, and exercise dependence) and four nodes representing total scores and subscales of transdiagnostic risk factors (emotion dysregulation, maladaptive perfectionism, social appearance anxiety, and negative urgency), along with thirteen items representing eating disorder symptoms (see Table 2 for abbreviations of nodes). EDE-Q items were used, rather than subscales or total scores, in order to capture specific eating disorder symptoms. EDE-Q items were reduced because use of the entire measure would have resulted in too many nodes for our sample size leading to unstable networks. The reduction of EDE-Q items used both theoretical and empirical methods from past research

studies (see Levinson, Brosf, et al., 2018 for full item selection procedure). The thirteen EDE-Q items selected were based off previous research that has demonstrated these items are representative of essential, non-overlapping eating disorder symptoms. These items were also shown to be more stable among networks with a similar sample size as ours and are more generalizable than using the entire EDE-Q measure (Vanzhula et al., under review).

Both the pre- and post-networks were estimated using the *estimateNetwork* function in the *bootnet* package in R (Epskamp, Maris, et al., 2018). Glasso networks were used, in which nodes are symptoms or risk factors and edges (i.e., connections among nodes) are partial Spearman correlations between two symptoms, while accounting for all other nodes in the network. Estimates of stability (i.e., the accuracy of the centralities calculated) were identified using the *bootnet* package in R (Epskamp, Maris, et al., 2018). Stability values must be adequate (>.25) to excellent (>.50) in order to interpret the networks (Epskamp, Borsboom, et al., 2018).

Strength centrality (i.e., the sum of the absolute value of all edges connected to a node) was identified using the *centralityplot* function in the *qgraph* package in R (Epskamp et al., 2012). Bridge strength (i.e., the sum of the absolute value of all of a node's edges excluding nodes in its symptom cluster) was calculated using the *bridge* function in the *networktools* package in R (Jones et al., 2019). Centrality difference tests were conducted using the *bootnet* package in R to determine if central and bridge symptoms were significantly *more central* than other symptoms in the network (Epskamp, Maris, et al., 2018). All central and bridge symptoms reported were more central than at least 75% of other nodes in the network based on these tests.

Differences between networks were tested using the *NetworkComparisonTest* package in R (van Borkulo et al., 2015). Three indices were used to determine network differences: network invariance (*M*; i.e., significant differences in maximum edge strength between networks or the

difference in network structure and interconnectivity between two networks), global strength invariance (*GSI*; i.e., significant differences in the sum of the edge strengths or differences in overall strength of symptom connections between two networks), and edge invariance (*E*; i.e., significant differences between individual edges across networks or differences in each individual symptom connection across two networks) (van Borkulo et al., 2015).

## Results

### Networks and Stability

The pre- and post-Body Project networks are both included in Figures 1 and 2. The stability of the pre-Body Project network was good ( $>.50$ ; CS-Strength = .67; CS-Bridge Strength = .67) (Epskamp, Borsboom, et al., 2018). The stability of the post-Body Project network was adequate ( $>.25$ ; CS-Strength = .36; CS-Bridge Strength = .28).

### Central Symptoms

The most central symptom in the pre-Body Project network was feared concerns about eating (*Strength* [*S*] = 2.33), which was more central than all other nodes in the network (see Figure 3). Other top central symptoms include: thinness/restricting expectancies (*S* = 1.30), eating disorder-related guilt (*S* = 1.22), and desire to lose weight (*S* = 1.08), all of which were more central than 76% of other nodes in the network.

The most central symptom in the post-Body Project network was feared concerns about eating (*S* = 2.18), which was more central than all other nodes in the network (see Figure 3).

### Bridge Symptoms

The most central bridge symptoms (when accounting only for relationships between risk factors and eating disorder symptoms) in the pre-Body Project network were thinness/restricting expectancies (*Bridge strength* [*BS*] = .61) and feared concerns about eating (*BS* = .58). These



bridge symptoms were significantly more central than 86%-90% of other nodes in the pre-network (see Figure 4). Thinness and restricting expectancies was uniquely correlated with desire for a flat stomach (part  $r = .15$ ), fear of weight gain (part  $r = .09$ ), desire to lose weight (part  $r = .09$ ), guilt (part  $r = .08$ ), loss of control over eating (part  $r = .07$ ), fear of others seeing your body (part  $r = .07$ ), feeling fat (part  $r = .03$ ), food rules (part  $r = .02$ ), and weight-based judgment of self (part  $r = .01$ ). Feared concerns about eating was uniquely correlated with fear of others seeing you eat (part  $r = .30$ ), fear of weight gain (part  $r = .09$ ), fasting (part  $r = .06$ ), desire to lose weight (part  $r = .06$ ), weight-based judgment of self (part  $r = .04$ ), and loss of control over eating (part  $r = .03$ ).

The most central bridge symptom in the post-Body Project network was thinness/restricting expectancies ( $BS = .53$ ). The bridge symptom of thinness/restricting expectancies was significantly more central than 81% of all other nodes in the post-network (see Figure 4). Thinness and restricting expectancies were uniquely correlated with weight-based judgement (part  $r = .17$ ), food rules (part  $r = .12$ ), desire to lose weight (part  $r = .09$ ), feeling fat (part  $r = .06$ ), binge eating (part  $r = .04$ ), guilt (part  $r = .03$ ), and fear of weight gain (part  $r = .02$ ).

Overall, bridge strength of the two networks decreased from pre-to post-network. Out of all nine individual risk factors, six risk factors decreased in bridge strength from pre- to post-network, while three increased in bridge strength. See Table 3 for differences in bridge strength for each risk factor.

### **Network Comparison Tests**

There were no significant differences in network invariance ( $M = .25, p = .406$ ) or global strength invariance ( $S = .52, p = .182$ ) between the pre- and post-Body Project networks. There

were 20 edges that were significantly different across the two networks, out of a total of 231 edges. See Table 4 for which edges were significantly different.

### **Discussion**

The current study used network analysis to examine eating disorder symptoms and risk factors. We examined both eating disorder-specific risk factors and transdiagnostic risk factors before and after an eating disorder prevention program called the Body Project. I first hypothesized that stronger connections would emerge between eating disorder-specific risk factors and eating disorder symptoms over transdiagnostic risk factors and eating disorder symptoms. Overall, this was supported, as three of the four top bridge symptoms in the pre-network were eating-disorder specific risk factors. I hypothesized that bridge symptoms would be fewer and weaker in the post-Body Project network, which was supported in that there was a reduction in bridge values from pre- to post-Body Project, and feared concerns about eating emerged as a central bridge symptom for the pre-network but did not remain central in the post-network. Additionally, bridge strength values did decrease for over half of the risk factors, however this was not significant. I also hypothesized that the connection between eating disorder-specific risk factors and eating disorder symptoms would result in significantly larger pre-post change than the transdiagnostic risk factors. This hypothesis was not supported, in that while several eating-disorder specific risk factor bridge symptoms did decrease across the two networks, more transdiagnostic risk factor bridge symptoms decreased from pre- to post-Body Project. My exploratory hypothesis, that the NCT would reveal significant differences pre- to post-Body Project was partially supported, with the NCT revealing twenty significantly different edges, whereas the network invariance and global strength invariance showed no significant differences.

Overall, the most central symptom in both the pre- and post-Body Project networks was feared concerns about eating. Feared concerns about eating encompasses the fears about the consequences of eating, including weight gain, social judgement, and how eating will make one feel physically (Levinson & Byrne, 2015). Specifically, it may not be food itself, but the feared associations between food and negative outcomes, that poses heightened risk for developing an eating disorder. This finding is in line with recent work that has emphasized the need for targeting cognitive aspects of eating disorders, including fear-learning mechanisms, rather than just behavioral aspects, as cognitive factors may be contributing to eating disorder symptomology (Levinson, Christian, et al., 2020). The Fear of Food Measure, which contains the feared concerns about eating subscale, is a relatively new self-report measure that has not previously been included in network analyses, but the current findings suggest that the emergence of feared concerns about eating as central in both networks may indicate that it is an important eating disorder-specific risk factor. These findings warrant further investigation of feared concerns about eating as a cognitive risk factor that is underlying the development of eating disorder symptoms and should be tested in future research to replicate this finding. Further, the fact that it remained central after implementation of the Body Project may suggest that the Body Project is not adequately targeting this risk factor as a central symptom through their current methods and may be improved by developing a module specific to feared concerns about eating, to address the role of food and feared outcomes in eating disorder development.

Thinness/restricting expectancies, eating disorder-related guilt, and desire to lose weight were also identified as highly central symptoms in the pre-Body Project network, but did not remain central in the post-network. Thinness/restricting expectancies and desire to lose weight are both eating disorder symptoms that the Body Project aims to target, so while the Body

Project may not be effectively targeting feared concerns about eating, it is worth noting the reduction of thinness/restricting expectancies and desire to lose weight as central symptoms. Interestingly, although the Body Project does not target eating disorder-related guilt, this symptom was also less central after implementation of the program. This finding may suggest that the Body Project is also reducing some symptoms that are not specifically targeted in the current program, consistent with past research (Christian et al., 2019). Consistent with network theory, it is possible that reductions in core symptoms targeted by the intervention may have downstream effects on related ED symptoms and risk factors, dismantling the connections that lead to ED development. More research is warranted as to the replicability of these findings and to determine the effectiveness of the Body Project in both reducing symptoms that are currently targeted and untargeted within the program.

The most central bridge symptoms in the pre-Body Project network were thinness/restricting expectancies and feared concerns about eating. Thinness/restricting expectancies is similar to feared concerns about eating in that they both involve expectancies that engagement in certain eating behaviors will result in either desirable (i.e., weight loss or thinness) or undesirable (i.e., negative social interactions, weight gain, anxiety about how one's body feels after eating) outcomes. Though these risk factors may be similar in some regards, my findings may suggest that thinness/restricting expectancies was more persistently connected to eating disorder symptoms, as it remained a central bridge symptom after the Body Project, suggesting the Body Project may be addressing the bridge symptom of feared concerns about eating in a way that thinness/restricting expectancies are not. Although feared concerns about eating remained a central symptom from pre- to post-Body Project, suggesting that it may remain strongly connected to other risk factors, the Body Project may simultaneously be decreasing

feared concerns about eating as a bridge symptom to eating disorder symptoms. Relatedly, thinness/restricting expectancies did not remain a central symptom from pre- to post-network, however it did remain a bridge symptom, suggesting that while it does not remain strongly connected to other risk factors, it remains strongly connected to eating disorder symptoms. Overall, eating disorder-specific risk factors related to expectations around eating behaviors and their outcomes, both positive and negative, are contributing to eating disorder risk in adolescents and could be more effectively targeted by prevention programs. Further research is needed to examine thinness/restricting expectancies and feared concerns about eating prospectively in adolescents to better understand how to prevent them from escalating into clinical eating disorders.

The one transdiagnostic risk factor that emerged as a top four bridge symptom was social appearance anxiety, which is consistent with the literature on the impact of social appearance anxiety on eating disorder development. Social appearance anxiety has been shown to predict eating disorder symptoms like shape and weight concern, body dissatisfaction, and bulimic symptoms, among others, over and above other domains of social anxiety (Levinson & Rodebaugh, 2012). Interestingly, when examining bridge strength from pre- to post-Body Project network for individual risk factors, more transdiagnostic risk factors decreased in bridge strength than eating disorder-specific risk factors. Although eating disorder-specific risk factors were more central overall, suggesting that they may be more strongly connected to other risk factors and eating disorder symptoms, decrease in bridge strength for transdiagnostic risk factors in the post-network may propose that the Body Project is disrupting the connections for transdiagnostic risk factors more effectively than eating disorder-specific risk factors.

The NCT comparing networks pre- and post-Body Project did not show any significant differences in global strength invariance or network invariance. Global strength invariance measures the density of connections in the network, or how strongly symptoms are interconnected within a network, which we expected to decrease in response to a prevention program. However, findings are mixed on whether global strength is an effective measure of symptom severity or if it can capture symptom change across interventions (Christian, Perko, et al., 2020). It would be worthwhile for future research to continue to examine how effective global strength is at identifying the risk factors that are contributing to eating disorder symptoms over time. In contrast, edge invariance did reveal twenty significantly different edges. Between the pre- and post-networks, the sum of bridge edges, or specific pairings of symptoms and risk factors, did decrease from pre- to post-Body Project, suggesting that some connections between risk factors and eating disorder symptoms are being weakened. Interestingly, although the overall sum of bridge edges decreased from pre- to post-network, out of the twenty edges that were significant, sixteen of the edges showed an increase in edge strength in the post-network, suggesting stronger connections between symptoms and risk factors after a prevention program. Observation of the edges was exploratory in this study, as individual edges are not as stable as other measures like centrality and bridge strength, and these findings may very well be due to chance. Further research is warranted into the utility of individual partial correlations in clinical networks, as our results were mixed, as well as replication of the edge differences observed in this study to determine their usefulness.

### **Strengths and Limitations**

The current study has several notable strengths. Both the pre- and post-Body Project networks were tested among adolescents, a critical stage for eating disorder development (Stice

et al., 2009). Additionally, although the participants were from two private schools, the schools were at differing socioeconomic levels and therefore lend support to the findings being more generalizable. Finally, this is the first study to examine the efficacy of an eating disorder prevention program at disrupting the connection between risk factors and eating disorder symptoms using network analysis. By testing these changes using multiple timepoints, we were able to conceptualize and visualize the differences occurring throughout the prevention program.

This study is not without limitations. The sample, though diverse in socioeconomic backgrounds, was entirely female and primarily white. The Body Project is a program designed specifically for young girls and women, as eating disorders most commonly emerge in and affect these groups (Stice et al., 2008). Regardless, a more diverse racial, ethnic, and mix-gendered sample would allow for more generalizable findings and could reveal important differences between these groups. Similarly, the sample obtained was from two private, all-girl, schools and did not examine adolescent girls within public schools, which limits our understanding of how effective this prevention program is among students from a co-ed public school. The sample size at follow-up was another limiting factor in the study. Out of the original 301 participants, only 160 completed follow-up questionnaires, which provided less information for the post-Body Project network analysis. Finally, the data was obtained through self-report questionnaires, which is limited by self-report biases and may have impacted adolescents' willingness to endorse certain eating disorder symptoms and risk factors.

### **Implications and Future Directions**

Our findings suggest prevention programs like the Body Project may be disrupting some, but not all, risk factor and symptom connections among adolescents at risk for developing eating disorders. In future studies, it will be important to test additional risk factors, both eating

disorder-specific and transdiagnostic, not included in this study in order to better understand what central and bridge symptoms/risk factors are driving eating disorder development among adolescents. Understanding more fully how these symptoms and risk factors are interacting will allow for more targeted prevention programs aimed at specific central and bridge symptoms to optimize their efficacy, which could decrease the incidence of eating disorders among adolescents. Future research should test these relationships among more diverse populations, regarding race, ethnicity, and gender, as well as among different age groups. Although eating disorders often emerge during adolescence, many age groups are affected by eating disorders and are subject to different risk factors, so understanding central and bridge symptoms among these groups could lead to better prevention programs and treatment in more severe instances.

Prevention and intervention targeted toward specific populations facing differing risk factors is especially important as eating disorders are extremely heterogenous and therefore require an understanding of risk factors for a multitude of races, ethnicities, genders, and ages. Future studies should also examine these models in a larger sample size, especially regarding follow-up compliance, for more comprehensive and generalizable results. Finally, these connections should be studied over a longer time period. The networks in this study were calculated four weeks apart, but examining a longer period of time, such as across one year, would provide more information on whether these changes from pre- to post-Body Project are lasting and maintaining significant improvement in eating disorder prevention.

## **Conclusion**

This study reveals important risk factors, including feared concerns about eating, thinness and restricting expectancies, and social appearance anxiety, that may be driving eating disorder development among adolescents. Although bridge edges and symptoms, such as feared concerns



about eating, did decrease during an eating disorder prevention program, more research is needed in order to improve and develop more effective prevention strategies for adolescents and to further investigate cognitive risk factors within eating disorder networks.

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**Figures and Tables**

Table 1

*Participant Demographic Information*

		<i>n</i> (%)	<i>M</i> (SD)	Range
Age			15.23 (.643)	14-17
Sex	Female	301 (100.0)		
Ethnicity	Non-Hispanic White	254 (84.4)		
	Asian or Asian-American	7 (2.3)		
	Non-Hispanic Black	12 (4.0)		
	Multiracial or Biracial	8 (2.7)		
	American Indian or Alaskan Native	2 (0.7)		
	Hispanic	18 (6.0)		
	Individuals above an EDE-Q cutoff of 2.3	97 (32.2)		

Table 2

*Node Abbreviation Index*

Abbreviation	Construct	How construct was measured
fasting	Fasting	EDE-Q item-Have you gone for long period of time (8 hours or more) without eating anything in order to influence your shape or weight?
foodrules	Rules about eating	EDE-Q item-Have you attempted to follow definite rules regarding your eating in order to influence your shape or weight; for example, a calorie limit, a set amount of food, or rules about what or when you should eat?
foodcon	Food interference on ability to concentrate	EDE-Q item-Has thinking about food or its calorie content interfered with your ability to concentrate on things you are interested in: for example, read, watch TV or follow a conversation?
losscontrol	Loss of control over eating	EDE-Q item-Have you experienced a sense of loss of control over eating?
bingeeating	Binge eating episodes	EDE-Q item-Have you had episodes of binge eating?
flatstomach	Desire for stomach to be flat	EDE-Q item-Have you had a definite desire for your stomach to be flat?
feargain	Fear of weight gain or becoming fat	EDE-Q item-Have you had a definite fear that you might gain weight or become fat?
feltfat	Felt fat	EDE-Q item-Have you felt fat?
desiretolose	Desire to lose weight	EDE-Q item-Have you had a strong desire to lose weight?
guilt	Guilt about shape or weight	EDE-Q item-On what proportion of times that you have eaten have you felt guilty become of your shape or weight? (Do not count binges.)
weightjudge	Weight influence on how you judge yourself	EDE-Q item-Has your weight influenced how you think about (judge) yourself as a person?
seeeat	Concern about others seeing you eat	EDE-Q item-How concerned have you been about other people seeing you eat?
seebody	Uncomfortable about others seeing your body	EDE-Q item-How uncomfortable have you felt about others seeing your body; for example, in communal changing rooms, when swimming or wearing tight clothes?
anxietyeat	Anxiety about eating	Fear of Food Measure, anxiety about eating subscale
fearedconcern	Feared concerns about eating	Fear of Food Measure, feared concerns about eating subscale
foodavoid	Food avoidance	Fear of Food Measure, food avoidance subscale

exdepend	Exercise dependency	Exercise Dependence Scale-Revised total score
thinrestrict	Thinness/restricting expectancies	Thinness and Restricting Expectancies Inventory total score
emoreg	Emotion regulation	State Difficulties in Emotion Regulation total score
mp	Maladaptive perfectionism	Frost Multidimensional Perfectionism Scale maladaptive perfectionism subscale
SAA	Social appearance anxiety	Social Appearance Anxiety Scale total score
negurg	Negative urgency	Urgency, Premeditation, Perseverance, and Sensation Seeking Impulsive Behavior Scale, negative urgency factor

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Table 3

*Bridge Strength Differences*

Risk Factor	Eating disorder-specific (ED) or transdiagnostic (T)	Bridge Strength Pre-Network	Bridge Strength Post-Network
foodavoid	ED	0.00738942	0.08836857
exdepend	ED	0.18697227	0.14666451*
anxietyeat	ED	0.23095535	0.27543679
fearedconcern	ED	0.58357303	0.25167984*
thinrestrict	ED	0.61154691	0.52520222*
mp	T	0.04082893	0.10959453
SAA	T	0.40861867	0.32018879*
negurg	T	0.18855026	0.06112698*
emoreg	T	0.22344186	0.15106732*

*Note.* \* represents a decrease in bridge strength from pre- to post-network. See Table 2 for descriptions of node abbreviations.

Table 4

*Significant Edge Differences across Networks*

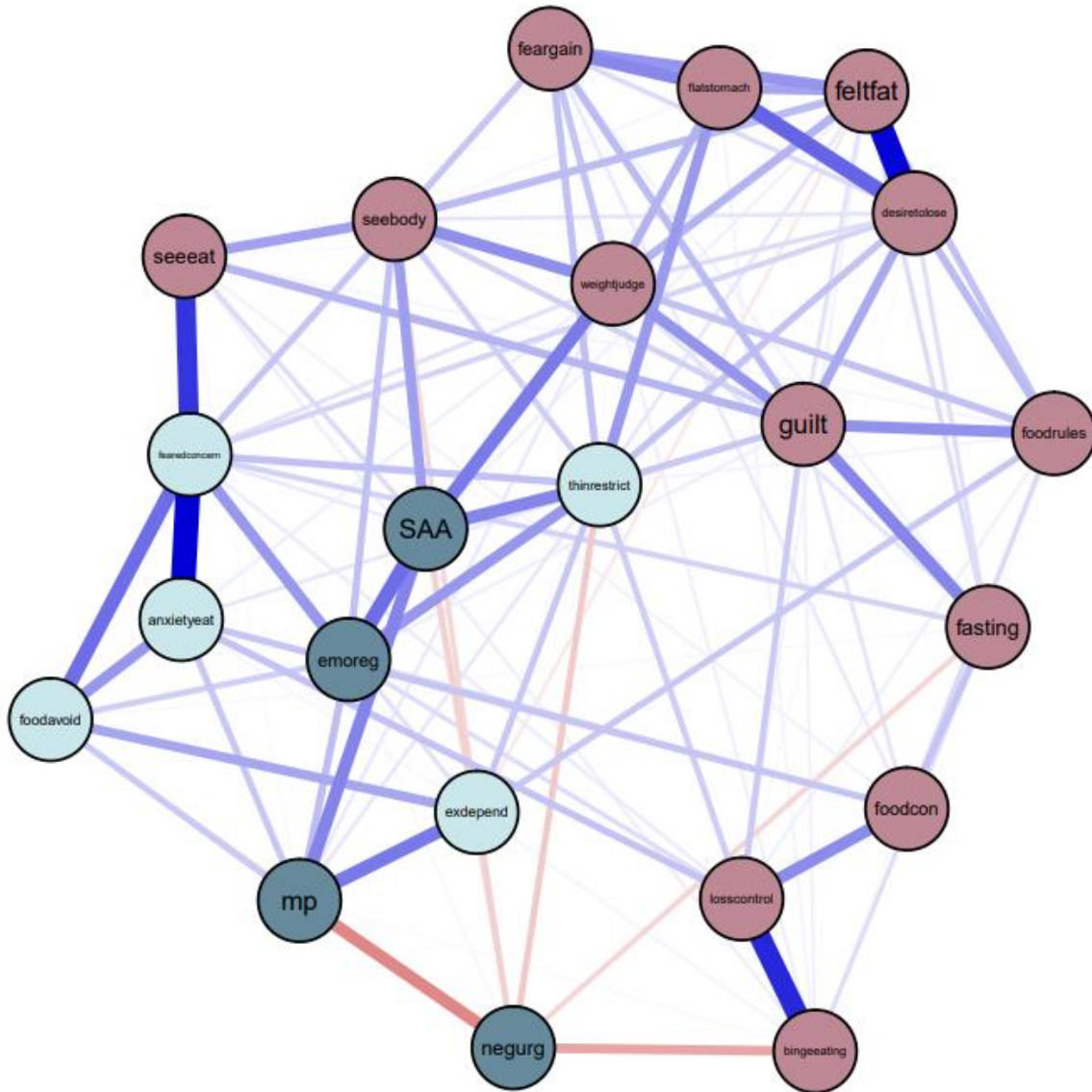
Edge	Pre-Body Project network partial correlation	Post-Body Project network partial correlation	<i>p</i> -value
Binge eating – anxiety about eating	.000	.002	.002
Weight-based judgement – thinness/restricting expectancies	.005	.170	.01
Fear of weight gain – anxiety about eating	.000	.000	.014
Loss of control – social appearance anxiety	.000	.028	.017
Fear of others seeing you eat – food avoidance	.000	.027	.021
Exercise dependence – anxiety about eating	.011	.134	.026
Fear of others seeing your body – anxiety about eating	.000	.000	.032
Food rules – fear of others seeing you eat	.013	.111	.033
Fear of others seeing your body – feared concerns about eating	.000	.029	.034
Weight-based judgement – social appearance anxiety	.196	.000	.037
Desire to lose weight – social appearance anxiety	.000	.015	.038
Maladaptive perfectionism – anxiety about eating	.082	.121	.039
Binge eating – feared concerns about eating	.000	.045	.041
Fear of weight gain – social appearance anxiety	.000	.115	.042
Fasting – loss of control	.000	.136	.044
Food rules – social appearance anxiety	.000	.000	.044

Social appearance anxiety – exercise dependence	-.067	.000	.046
Food rules – loss of control	.021	.131	.048
Weight-based judgement – fear of others seeing you eat	.000	.135	.048
Fear of others seeing your body – exercise dependence	-.057	.000	.048

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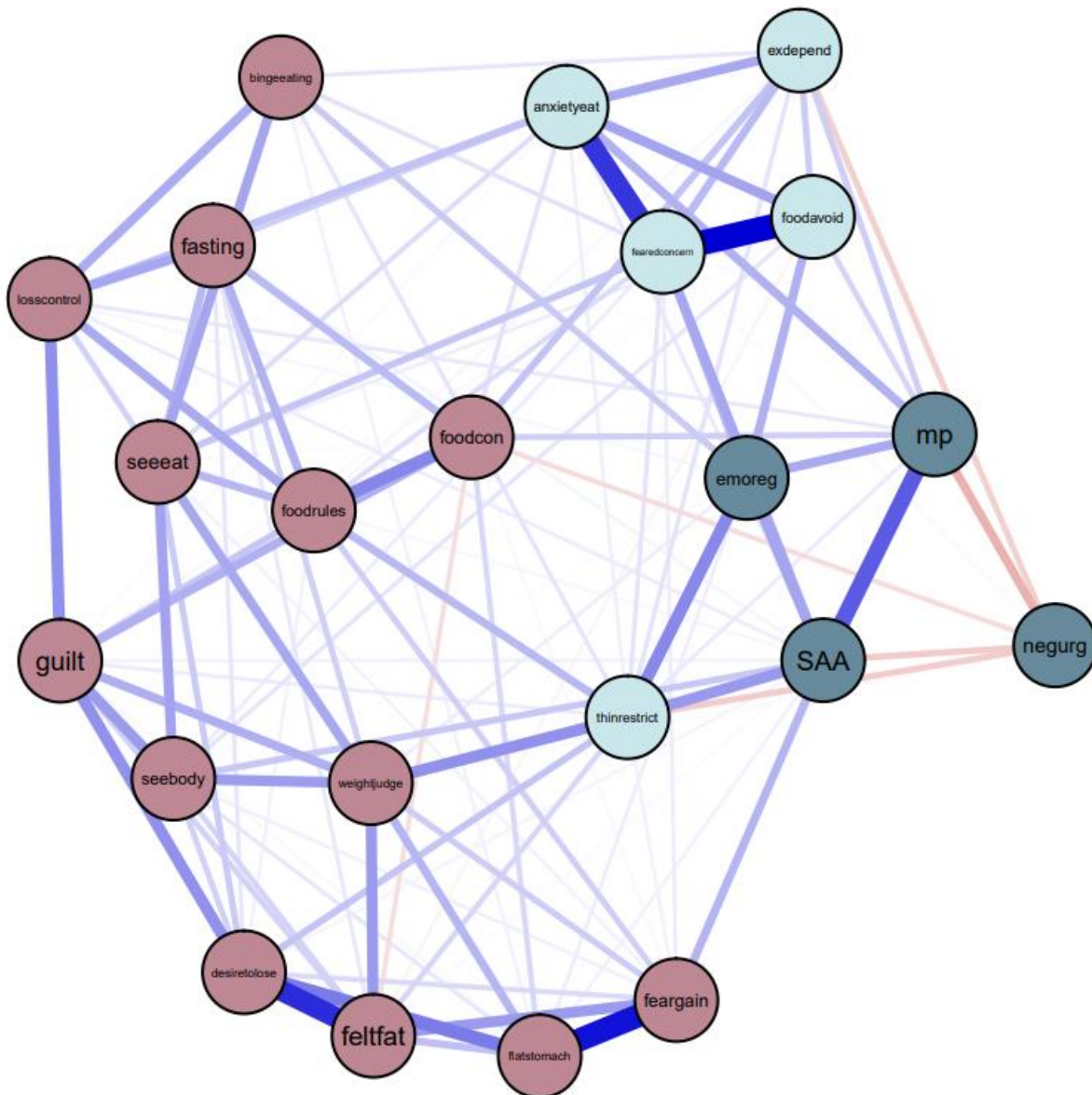


Figure 1.

*Pre-Body Project Network*

*Note.* Lines represent the strength of partial correlations, with thicker lines indicating stronger partial correlations. Blue lines represent positive correlations while red lines represent negative correlations. Eating disorder symptoms are indicated by the pink nodes, eating disorder-specific risk factors are indicated by the light blue nodes, and transdiagnostic risk factors are indicated by the dark blue nodes. See Table 2 for descriptions of node abbreviations.

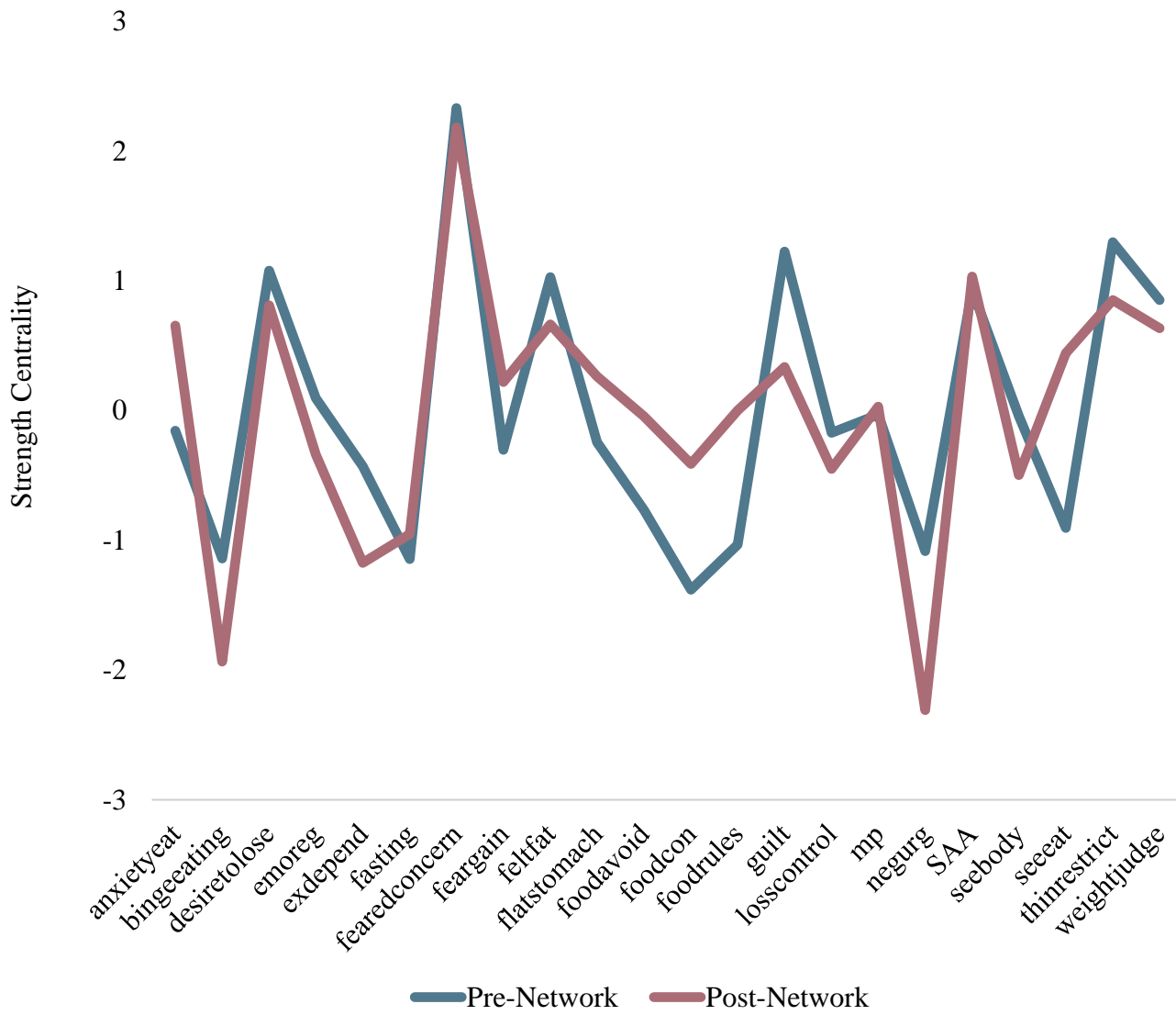
Figure 2

*Post-Body Project Network*

*Note.* Lines represent the strength of partial correlations, with thicker lines indicating stronger partial correlations. Blue lines represent positive correlations while red lines represent negative correlations. Eating disorder symptoms are indicated by the pink nodes, eating disorder-specific risk factors are indicated by the light blue nodes, and transdiagnostic risk factors are indicated by the dark blue nodes. See Table 2 for descriptions of node abbreviations.

Figure 3

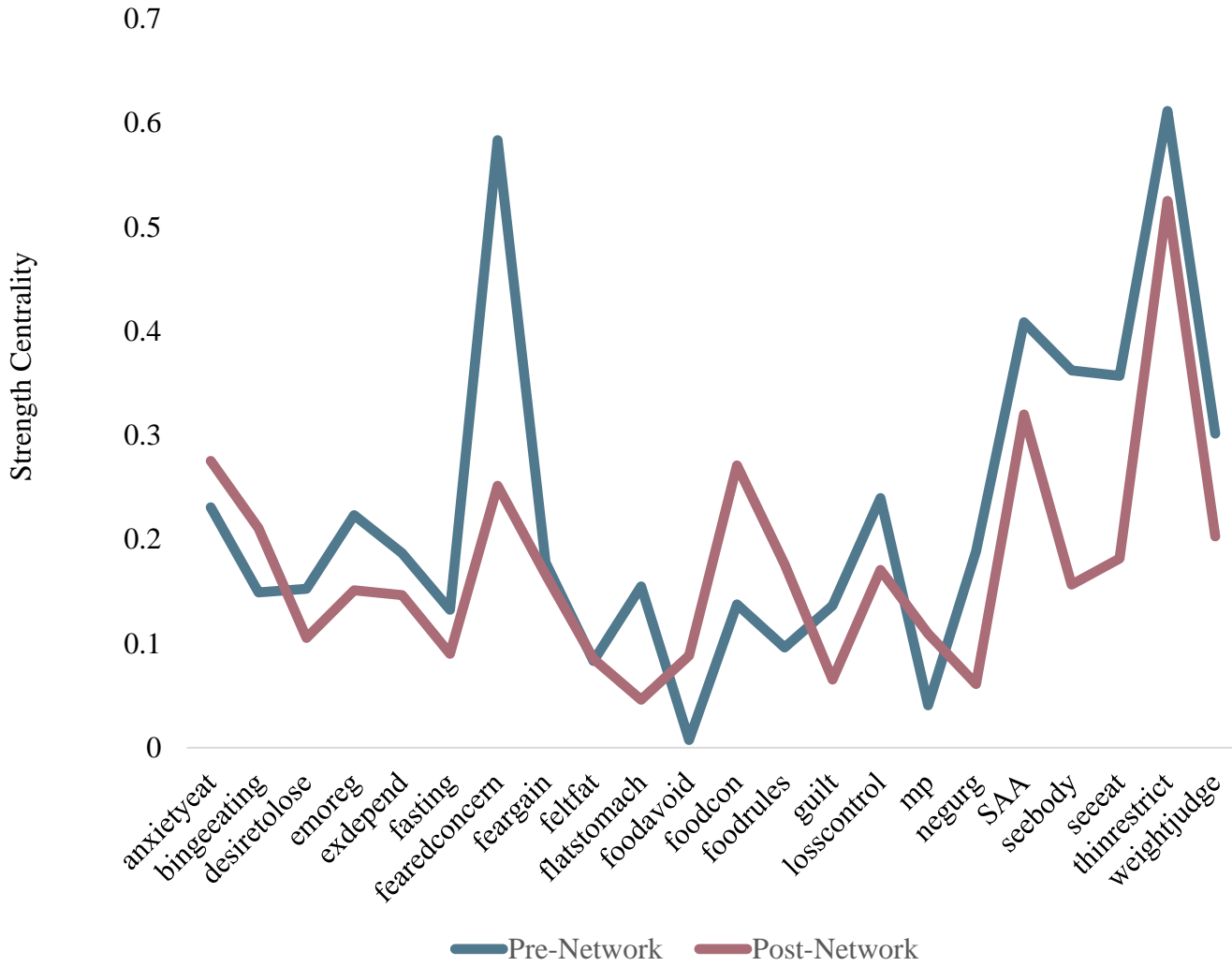
Centrality Graph



Note. See Table 2 for descriptions of node abbreviations.

Figure 4

*Bridge Strength Graph*



*Note.* See Table 2 for descriptions of node abbreviations.