Research Square

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

A network analysis of barriers to physical activity and depressive symptoms in pregnant women with prepregnancy overweight or obesity

Yiyun Yang
Women's Hospital of Nanjing Medical University(Nanjing Women and Children's Healthcare Hospital)
Shasha Luo
Women's Hospital of Nanjing Medical University(Nanjing Women and Children's Healthcare Hospital)
Lei Ding
Women's Hospital of Nanjing Medical University(Nanjing Women and Children's Healthcare Hospital)
Chunjian Shan
Women's Hospital of Nanjing Medical University(Nanjing Women and Children's Healthcare Hospital)
Yu Wang
Nanjing Medical University
Juan Wang
Women's Hospital of Nanjing Medical University(Nanjing Women and Children's Healthcare Hospital)
Zhu Zhu
zz6323780126.com

Women's Hospital of Nanjing Medical University(Nanjing Women and Children's Healthcare Hospital)

Research Article

Keywords: Barriers, Physical activity, Depressive symptoms, Pregnant women, Network analysis

Posted Date: March 18th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8870381/v1

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

Additional Declarations: No competing interests reported.

Abstract

Background

Previous research has shown that depressive symptoms are associated with barriers to physical activity in pregnant women with prepregnancy overweight or obesity. However, there is currently not much research exploring the dynamic interactions between these concepts. This study aimed to explore the complex network relationship between barriers to physical activity and depressive symptoms in pregnant women with prepregnancy overweight and obesity.

Method

This cross-sectional study was conducted from May to October 2025 at two Asian hospital obstetric outpatient clinics in Nanjing and Yangzhou, Jiangsu Province, China. A total of 813 pregnant women with prepregnancy overweight or obesity were enrolled. Barriers to physical activity and Depression were assessed using the Barriers to Physical Activity during Pregnancy Scale (BPAPS) and the Hospital Anxiety and Depression Scale (HADS), respectively. Central and bridge symptoms were identified through centrality and bridge centrality indices. Network stability and accuracy were evaluated, and age-group differences were examined using the Network Comparison Test.

Results

The average age of the participants in the study was 30.57 years old (SD = 3.57), and 723 (88.9%) lived in urban areas. The overall network demonstrated high stability, with HADS3 (I feel cheerful), HADS5 (I look forward with enjoyment to things), and BPAPS1 (Pregnancy-related intrapersonal barriers) identified as central nodes. BPAPS1 (Pregnancy-related intrapersonal barriers), BPAPS3 (Interpersonal barriers), and BPAPS4 (Environmental barriers) emerged as key bridge nodes linking barriers to physical activity and depressive symptoms. The edge connecting BPAPS1 (Pregnancy-related intrapersonal barriers) and HADS3(I feel cheerful) represented the strongest inter-community connection in the network. The global connectivity strength of individuals over 30 years old is significantly stronger than that of those under 30 years old(over 30 years old = 5.04, under 30 years old = 3.92, p = 0.006).

Conclusions

The identification of central and bridge symptoms holds promise for enabling early detection and guiding targeted interventions to address barriers to physical activity and depressive symptoms among pregnant women with prepregnancy overweight or obesity, with consequent benefits for maternal and infant health outcomes.

1. Introduction

With the continuous rise in the global rate of overweight and obesity, this phenomenon has become a major challenge affecting public health. The prevalence of overweight and obesity among women of childbearing age is steadily increasing worldwide year by year[1–3]. Currently, approximately 2.5 billion adults worldwide are overweight, with 890 million identified as obese. This represents 44% of women aged 18 and above, including those of childbearing age range[4]. In China, 21.05% of childbearing-age women are overweight, and 6.08% are obese[5]. Overweight and obese mothers are more likely to develop gestational diabetes mellitus (GDM), hypertension, preeclampsia (PE), and birth complications[6–8]. Fetuses are at risk of macrosomia, congenital anomalies, hypoglycemia, and preterm birth[9, 10].

Growing evidence shows that regular physical activity during pregnancy substantially benefits the mother and fetus. Physical activity aids with the maintenance of improved sleep and reduced symptoms of postpartum depression, along with reducing the risk of gestational diabetes and preeclampsia[11–13]. In addition, physical activity during pregnancy can have a positive impact on postpartum health and reduce child's risk of chronic diseases such as obesity, diabetes, and cardiovascular diseases in the future[14–16]. Guidelines from the World Health Organization and multiple countries recommend that women without pregnancy-related contraindications or complications should engage in at least 150 minutes of moderate-intensity physical activity per week[17]. Despite well-documented health benefits, most pregnant women fail to meet the recommended physical activity guidelines. The barriers to physical activity refer to the obstacles individuals face when engaging in, maintaining, or increasing their physical activity, including pregnancy-related intrapersonal barriers, non-pregnancy related intrapersonal barriers, interpersonal barriers, and environmental barriers[18]. Compared to pregnant women with normal weight, those who were prepregnancy overweight and obese may experience physiological discomforts such as breathing difficulties and increased joint pressure due to physical activity, as well as psychological discomforts such as frustration caused by body image issues and lack of confidence in physical activity[19, 20]. These factors made them encounter more barriers to physical activity, resulting in a decrease in their physical activity enthusiasm.

In addition to the known impact of overweight and obesity on physical activity in pregnant women, elevated pre-pregnancy body-mass index (BMI) is closely associated with perinatal mood disorders. The relationship between obesity and mood disorders is characterized by a complex bidirectional reciprocity; depression predisposes individuals to obesity, while obesity concurrently increases vulnerability to depressive symptoms[21, 22]. Individuals with overweight had a 19% higher risk of developing depression during pregnancy compared to those with normal weight, and a 9% higher risk of developing postpartum depression[23]. Furthermore, individuals with pre-existing obesity during pregnancy demonstrated a 33% elevated risk of antenatal depression and a 39% increased risk of postpartum depression compared with those with normal weight[24]. Maternal depression is associated with a spectrum of adverse outcomes spanning maternal and child health, family functioning, and child developmental trajectories. In pregnant women, depression often manifests as persistent low mood,

loss of interest, and sleep disturbances; in severe cases, it may progress to suicidal ideation or self-harm behaviors[25, 26]. Substantial evidence indicates that prenatal maternal depression may compromise mother-infant bonding, consequently manifesting in infant feeding difficulties, sleep disruptions, and developmental delays. Furthermore, prolonged exposure to maternal depressive symptoms during early critical periods is associated with elevated risks across offspring's cognitive, emotional, and social developmental domains[27].

Moderate physical activity during pregnancy has a clear and positive impact on preventing and alleviating depression. A scoping review demonstrated that physical activity interventions effectively alleviate symptoms of postpartum depression[28]. A study found that physical activities have great benefits for improving depression, anxiety, and discomfort symptoms in people with confirmed mental health issues[29].

Network analysis could indicate core symptoms that exert the strongest influence on the entire symptom network. The core symptoms may help identify the key pathogenesis of the mental illness; these core symptoms largely determine the normal functioning of the network, so intervening in treatment specifically targeting these symptoms may lead to more ideal outcomes. The application of network analysis in psychological and psychiatric domains has expanded significantly in recent years. This study investigated the correlation between physical activity barriers and depressive symptoms among a large group of representative pregnant women with prepregnancy overweight and obese through network analysis. The study primarily aimed to identify central and bridge symptoms within the network, while simultaneously evaluating the stability and accuracy of the estimated model.

2. Methods

2.1. Participants

This multicenter, cross-sectional survey was conducted from May to October 2025. Participants were pregnant women with prepregnancy overweight and obese in Nanjing Women and Children's Healthcare Hospital and Yangzhou Maternal and Child Health Hospital during the study period. The inclusion criteria were BMI≥25kg/m^2 before pregnancy, singleton pregnancy, aged over 18 years and could read and write in Chinese. Women with absolute contraindications for physical activity (eg, preeclampsia, cervical insufficiency, or unexplained persistent vaginal bleeding) during pregnancy were excluded.

2.2. Measures

2.2.1. Basic information sheet

Participants’ basic socio-demographic information was collected, including age, place of residence, education, monthly income, employment status, medical payment method, gestational week, number of pregnancy, conception method, planned delivery method.

2.2.2. Barriers to physical activity

The Barriers to Physical Activity during Pregnancy Scale (BPAPS), developed by Amiri-Farahani and colleagues[18], is a 29-item self-report scale used to measure the barriers of physical activity during pregnancy. It includes four factors, including pregnancy-related intrapersonal barriers, non-pregnancy related intrapersonal barriers, interpersonal barriers, and environmental barriers. Responses to the BPAPS are scored on a Likert 5-point scale as follows: 5 = strong agreement, 4 = agreement, 3 = neutral, 2 = disagreement, and 1 = strong disagreement. Based on the results obtained, the total score of BPAPS can range from 29 to 145 with a higher score associated with greater barriers to physical activity during pregnancy. Internal consistency and stability of the scale was confirmed by a Cronbach alpha coefficient of 0.824 and a test-retest reliability score of 0.87. The Chinese version of BPAPS has been proven reliable in the pregnant women population[30], with a Cronbach's alpha of 0.952 in this study.

2.2.3. Depression

The Hospital Anxiety and Depression Scale (HADS), developed by Zigmond and Snaith[31], is a 14-item self-report scale used to measure the severity of anxiety and depression. This study focused on the depression dimension (7 items), using a 4-point scoring method (0–3), resulting in a total score range of 0–21, with higher scores representing a greater severity of depressive symptoms[32]. The Chinese version of HADS-D has been proven reliable in the pregnant women population[33, 34], with a Cronbach's alpha of 0.714 in this study.

2.3 Statistical analysis

In this study, the statistical analysis of scale scores and the descriptive analysis of demographic data were performed using SPSS version 27.0. R software (version 4.4.3) was used to construct and analyse the network structures.

2.3.1. Network estimation

The network analysis was conducted using R software(version 4.4.3). The “EBIC glasso” model was employed to estimate the network structure[35]. This network is composed of different nodes and edges. Each node represents an item or dimension, and the relationships between nodes are represented by edges. The thickness of edges reflects the strength of the correlation, with thicker edges indicating stronger correlation. The blue edge represents a positive correlation, while the red edge represents a negative correlation. Stronger correlation is intuitively reflected through nodes that are closer in spatial position to each other. The Least Absolute Shrinkage and Selection Operator (LASSO) and Extended Bayesian Information Criterion (EBIC) are used to compress edges in the network and select relevant adjustment parameters, making the network more concise and easier to interpret. The “estimateNetwork” function in the R package “bootnet” is used for network estimation. The visualization of the network is achieved through the R package “qgraph”[36].

2.3.2. Centrality and bridge estimate

The direct relationship between a node and other nodes is measured by its centrality. We used the centralityPlot function in the R graph package to calculate three centrality metrics: strength, closeness, and betweenness, in order to determine the relative importance of each node in the network. The networktools R software package was used to calculate the bridge centrality statistics, such as bridge strength, bridge betweenness, and bridge closeness[37]. The strength centrality is the sum of the weighted values of the connecting lines of the node, indicating the overall correlation of the symptom in the network. In this study, based on the standardized bridge strength values of the network, the nodes with the top 20% scores were selected as the predicted bridge nodes.

2.3.3. Network accuracy and stability estimation

To test the robustness of the estimation network, we used the R software package bootnet to estimate the accuracy of edge weights and the stability of node strength. Firstly, by non parametric bootstrap, a 95% confidence interval (CI) was calculated to evaluate the accuracy of edge weights[38]. Secondly, we used bootstrap difference testing to evaluate the difference between edge weights and centrality indices. The results with lower CI overlap showed more accurate edge weights. The correlation stability coefficient (CS-C) was also used to evaluate the strength of stability. Researchers believe that CS-C should ideally be greater than 0.5, but at least higher than 0.25[39].

2.3.4. Network comparison

To examine potential age differences in barriers to physical activity and depression, we used the “NetworkComparisonTest” package to compare networks across different gender subgroups. We tested the differences in network structure, global strength, and significant edges.

3. Results

3.1.Sample characteristics

In total, 813 questionnaires were eligible for analysis. The average age of the participants in the study was 30.57 years old (SD = 3.57), and 723 (88.9%) lived in urban areas. The average score for BPAPS and HADS was 98.93 (SD = 17.04) and 10.19 (SD = 2.75) respectively, and all nodes of the BPAPS and HADS were described (see Table 1).

Table 1

Description of network nodes.

Node name	Item content	M	SD
BPAPS1	Pregnancy-related intrapersonal barriers	37.10	7.09
BPAPS2	Non-pregnancy related intrapersonal barriers	16.67	3.53
BPAPS3	Interpersonal barriers	15.57	3.48
BPAPS4	Environmental barriers	29.60	6.09
HADS1	I still enjoy the things I used to enjoy	1.67	0.68
HADS2	I can laugh and see the funny side of things	1.84	0.76
HADS3	I feel cheerful	1.31	0.72
HADS4	I have lost interest in my appearance	1.18	0.54
HADS5	I look forward with enjoyment to things	1.26	0.66
HADS6	I feel as if I am slowed down	1.70	0.58
HADS7	I can enjoy a good book or radio or TV programme	1.23	0.57
BPAPS total scale		98.93	17.04
HADS total scale		10.19	2.75

Note: M: Mean; SD: Standard Deviation. BPAPS: Barriers to Physical Activity during Pregnancy Scale. HADS: Hospital Anxiety and Depression Scale

3.2. Network structure

Fig. 1 shows the network architecture of the relationship between barriers to physical activity and depressive symptoms. The density of this network was relatively high (0.58, 32/55), with an average weight of 0.07. All edges were positively correlated. The strongest association between barriers to physical activity symptoms were BPAPS3 (Interpersonal barriers) and BPAPS4 (Environmental barriers), and the strongest association between depressive symptoms were HADS3 (I feel cheerful) and HADS5 (I look forward with enjoyment to things), with the strongest edges being BPAPS1 (Pregnancy-related intrapersonal barriers) - HADS3(I feel cheerful) and BPAPS3 (Interpersonal barriers) -HADS3 (I feel cheerful) and BPAPS1 (Pregnancy-related intrapersonal barriers) - HADS6 (I feel as if I am slowed down). BPAPS2 (Non-pregnancy related intrapersonal barriers) had the highest predictability (0.676), while HADS6 (I feel as if I am slowed down) had the lowest predictability(0.137).

3.3. Centrality and bridge centrality

The centrality results (Fig. 2) showed that HADS3 (I feel cheerful), HADS5 (I look forward with enjoyment to things), and BPAPS1 (Pregnancy-related intrapersonal barriers) were the symptoms with the highest connectivity compared to other symptoms in the network (highest strength values). In contrast, HADS6 (I feel as if I am slowed down) and HADS4 (I have lost interest in my appearance) had the lowest strengths,

indicating that they may be borderline symptoms. In addition, the bridge strength index (Fig. 3) indicated that BPAPS1 (Pregnancy-related intrapersonal barriers), BPAPS3 (Interpersonal barriers), and BPAPS4 (Environmental barriers) were the bridge symptoms that promote the coexistence of barriers to physical activity and depressive symptoms, suggesting that they had the strongest ability to enhance barriers to physical activity and depressive symptoms in the existing network.

3.4. Network stability and accuracy

Figure 4 shows the stability of strength centrality. It was worth noting that the CS-C value of the strength was 0.750; this indicated that the network had good stability (after dropping 70% of cases from the overall sample). Edge accuracy analysis showed that the 95% CIs for most edges were narrower; this indicated that the accuracy of the network was higher (Figure 5). In addition, edge and strength difference tests based on the "boot network" method show that the strongest edges and nodes differ significantly from the other edges and nodes; this also reflected the high accuracy of the estimation results of the constructed network (Figure 6 and Figure 7).

3.5. Network comparison

The NetworkComparisonTest results showed significant differences in network structure ($p = 0.024$) and global strength (over 30 years old = 5.04, under 30 years old = 3.92, $p = 0.006$) between pregnant womenwith prepregnancy overweight and obese over 30 years old and under 30 years old. Additionally, 13 out of the total edges exhibited significant differences in edge weights between the two age networks.

4. Discussion

This study explored the interrelationship between barriers to physical activity and depressive symptoms among pregnant Chinese women with prepregnancy overweight and obese from the perspective of network analysis. The study revealed a densely connected network in which HADS3 (I feel cheerful) and HADS5 (I look forward with enjoyment to things) emerged as the most central nodes. BPAPS1 (Pregnancy-related intrapersonal barriers) serves as the most crucial bridge node within this network, indicating its pivotal role in linking physical activity barriers with depressive symptoms. Furthermore, this study also explored the influence of age differences on the relationship between barriers to physical activity and depressive symptoms in pregnant women with prepregnancy overweight and obese.

We found that HADS3 (I feel cheerful) occupies the most central symptom within the barriers to physical activity–depression network. This finding indicated the symptom serves as the most critical node in activating and sustaining the interconnected pathological network, consistent with previous research finding. In a recent network analysis of depression symptomatology among pregnant women exposed to childhood adversity, the item “I feel cheerful” scored higher and exhibited higher strength centrality[40]. Similarly, the analysis of the depression-anxiety network among pregnant women also indicated that “sad or miserable” holds a central position[41]. Pregnant women with prepregnancy overweight and

obese may already experience body dissatisfaction and anxiety. Gestational weight gain may further intensify these negative body perceptions, fostering feelings of control loss and shame, and potentially becoming a trigger for depression. BPAPS1 (Pregnancy-related intrapersonal barriers) emerged as another central symptom, suggesting that pregnant women with prepregnancy overweight and obese tends to exhibit barriers to physical activity resulting from pregnancy-specific somatic discomfort. Pregnant women with prepregnancy overweight and obese may already experience gastrointestinal symptoms, including gastroesophageal reflux, abdominal distension, and constipation, attributabled to excess weight burden. These discomforts may be aggravated by physical activity during pregnancy, prompting active avoidance of physical activity[42]. Therefore, in this study, symptoms with higher centrality may exert the strongest influence on overall network structure and represent potential intervention targets, which would most likely facilitate transition of the entire network toward a healthier state.

BPAPS1 (Pregnancy-related intrapersonal barriers), BPAPS3 (Interpersonal barriers), and BPAPS4 (Environmental barriers) were identified as bridging symptoms connecting barriers to physical activity with depression. Specifically, pregnancy-related intrapersonal barriers to physical activity, including lack of energy, drowsiness, swelling, pains, and shortness of breath, were the most significant barriers reported by our study participants. The qualitative research results of a study found that fatigue, physical pain (back pain, leg pain), dizziness, morning sickness, and laziness are common obstacles[43]. Another systematic review has also reported tiredness, nausea and vomiting, pelvic girdle pain, and other pregnancy-related symptoms constitute common barriers to physical activity among overweight and obese pregnant women[44]. Nevertheless, physical activity during pregnancy enhances immune function, improves circulation, and effectively alleviates these discomforts. Overweight and obese pregnant women often refrain from physical activity due to safety concerns for themselves and their fetus, prioritizing uncomplicated delivery over physical activity[45]. Notably, this protective focus frequently extends to prioritizing fetal health at the expense of their own well-being. This indicates indicate that prepregnancy overweight and obese warrant targeted attention when accompanied by pregnancy-related discomfort. Healthcare providers should offer tailored support and guidance, clarify the interrelationships among maternal weight status, pregnancy physiology, and physical activity, and thereby enhance physical activity adherence. Furthermore, the symptom “Interpersonal barriers” was a bridge symptom, including insufficient familial and social support, inadequate healthcare guidance regarding safe physical activity implementation and its benefits, limited access to comprehensive information, and the influence of sociocultural norms. Previous studies have also similarly demonstrated the critical role of family and friends in shaping pregnant women's risk perceptions regarding physical activity[46, 47]. In fact, the support from family members can be an important source of encouragement and motivation for pregnant women with prepregnancy overweight and obese to adhere to their physical activity beliefs and behaviors. Relative to other family members, spousal attitude plays a particularly critical role in pregnant women's physical activity maintenance[48]. Another bridge symptom in this study was “Environmental barriers”, including inappropriate natural and climatic conditions, lack of physical space and facilities, accessibility and economic limitations of physical activity, and safety

concerns. In fact, facility availability constitutes one of the most critical environmental determinants of physical activity across diverse community settings[49]. Therefore, efforts to increase physical activity should focus on planning dedicated activity venues and equipping them with specialized equipment, such as air-conditioned gyms and community sports centers—and enhancing public awareness of the benefits of physical activity during pregnancy. Pregnant women with pre-pregnancy overweight or obesity may also adopt “zero-time exercise” strategies, fragmenting and reducing physical activity intensity to integrate movement into daily routines, thereby alleviating barriers and promoting adherence to physical activity.

“Pregnancy-related intrapersonal barriers” (BPAPS1) and “I feel cheerful” (HADS3) exhibited the strongest interconnection within the network model. A systematic review found that physical activity during pregnancy can alleviate depressive symptoms in pregnant women both during pregnancy and after childbirth[50]. Shakeel also found that pregnant women who met physical activity standards during pregnancy exhibited a reduced risk of postpartum depression[51]. Physical activity during pregnancy enhances cardiovascular function, improves vascular contractility and permeability, maintains normal nerve fiber conductivity, stimulates neurotransmitter secretion, and thereby helps alleviate negative emotions[52]. Furthermore, One study suggests that anxiety as a mediator in the relationship between physical activity during pregnancy and blood pressure. Engaging in physical activity during early pregnancy may alleviate anxiety symptoms, thereby contributing to blood pressure stabilization throughout gestation[52].

The global connectivity strength of older pregnant women with prepregnancy overweight and obese was significantly higher than that of younger pregnant women. Older pregnant women typically assume greater household and caregiving responsibilities alongside increased occupational demands, leaving limited time and energy for physical activity participation[53]. As maternal age advances, pregnant women experience a progressive decline in physical function and physical activity capacity. This age-related physiological deterioration manifests in diminished physical activity endurance and an increased propensity for discomfort symptoms, including tiredness, lower back pain, and peripheral edema, ultimately resulting in reduced physical activity tolerance[54]. Older primiparous women who reduce their physical activity due to concerns about miscarriage are significantly more likely to experience insufficient physical activity. Furthermore, advanced maternal age is associated with a higher incidence of pregnancy-related complications. These morbidities inherently restrict physical activity, while excessive anxiety regarding fetal preservation further compounds this reduction[55]. Older pregnant women experience more pronounced fluctuations in estrogen and progesterone levels, coupled with age-related decline in neurotransmitter regulation, which increases their vulnerability to low mood.

This study has several limitations. Firstly, as a cross-sectional study, we could not establish causal relationships. Future research should employ longitudinal designs tracking the entire pregnancy trajectory, with assessments stratified by trimester (early, middle, and late) to examine the dynamic interplay between barriers to physical activity and depression among pregnant women with prepregnancy overweight and obese. Secondly, our findings relied exclusively on self-reported measures

without clinical diagnostic validation. Future studies should corroborate these results using standardized clinical assessments to ensure diagnostic accuracy. Thirdly, as the data was collected from two hospitals in Jiangsu Province, the representativeness of the sample was limited; A multi center large sample study will be conducted in the future.

Despite these limitations, this study offers several strengths. To our knowledge, this is the first investigation to apply network analysis to examine the interrelationships between barriers to physical activity and depressive symptoms in pregnant women with prepregnancy overweight or obesity. This study indicates that HADS3 (I feel cheerful), HADS5 (I look forward with enjoyment to things), and BPAPS1 (Pregnancy-related intrapersonal barriers) are the core symptoms within the network of barriers to physical activity and depressive symptoms in pregnant women who were overweight or obese before pregnancy. Furthermore, BPAPS1 (Pregnancy-related intrapersonal barriers), BPAPS3 (Interpersonal barriers), and BPAPS4 (Environmental barriers) emerged as bridge symptoms connecting barriers to physical activity to depressive symptoms in pregnant women with prepregnancy overweight or obesity. These findings provide a theoretical foundation for developing targeted nursing interventions aimed at reducing barriers to physical activity and mental health morbidity among pregnant women with prepregnancy overweight and obesity, ultimately improving maternal and neonatal outcomes.The observed variations in network structure and global strength among pregnant women with prepregnancy overweight and obesity across different age groups underscore the importance of considering age-related differences when designing interventions.

This study explored the interrelationship between barriers to physical activity and depressive symptoms among pregnant Chinese women with prepregnancy overweight and obese from the perspective of network analysis. The study revealed a densely connected ne

We found that HADS3 (I feel cheerful) occupies the most central symptom within the barriers to physical activity–depression network. This finding indicated the symptom serves as the most critical node in activating and sustaining the interconnected

BPAPS1 (Pregnancy-related intrapersonal barriers), BPAPS3 (Interpersonal barriers), and BPAPS4 (Environmental barriers) were identified as bridging symptoms connecting barriers to physical activity with depression. Specifically, pregnancy-related intrapersonal barriers to physical activity, including lack of energy, drowsiness, swelling, pains, and shortness of breath, were the most significant barriers reported by our study participants. The qualitative research results of a study found that fatigue, physical pain (back pain, leg pain), dizziness, morning sickness, and laziness are common obstacles[43]. Another systematic review has also reported tiredness, nausea and vomiting, pelvic girdle pain, and other pregnancy-related symptoms constitute common barriers to physical activity among overweight and

obese pregnant women[44]. Nevertheless, physical activity during pregnancy enhances immune function, improves circulation, and effectively alleviates these discomforts. Overweight and obese pregnant women often refrain from physical activity due to safety concerns for themselves and their fetus, prioritizing uncomplicated delivery over physical activity[45]. Notably, this protective focus frequently extends to prioritizing fetal health at the expense of their own well-being. This indicates indicate that prepregnancy overweight and obese warrant targeted attention when accompanied by pregnancy-related discomfort. Healthcare providers should offer tailored support and guidance, clarify the interrelationships among maternal weight status, pregnancy physiology, and physical activity, and thereby enhance physical activity adherence. Furthermore, the symptom “Interpersonal barriers” was a bridge symptom, including insufficient familial and social support, inadequate healthcare guidance regarding safe physical activity implementation and its benefits, limited access to comprehensive information, and the influence of sociocultural norms. Previous studies have also similarly demonstrated the critical role of family and friends in shaping pregnant women's risk perceptions regarding physical activity[46, 47]. In fact, the support from family members can be an important source of encouragement and motivation for pregnant women with prepregnancy overweight and obese to adhere to their physical activity beliefs and behaviors. Relative to other family members, spousal attitude plays a particularly critical role in pregnant women's physical activity maintenance[48]. Another bridge symptom in this study was “Environmental barriers”, including inappropriate natural and climatic conditions, lack of physical space and facilities, accessibility and economic limitations of physical activity, and safety concerns. In fact, facility availability constitutes one of the most critical environmental determinants of physical activity across diverse community settings[49]. Therefore, efforts to increase physical activity should focus on planning dedicated activity venues and equipping them with specialized equipment, such as air-conditioned gyms and community sports centers—and enhancing public awareness of the benefits of physical activity during pregnancy. Pregnant women with pre-pregnancy overweight or obesity may also adopt “zero-time exercise” strategies, fragmenting and reducing physical activity intensity to integrate movement into daily routines, thereby alleviating barriers and promoting adherence to physical activity.

“Pregnancy-related intrapersonal barriers” (BPAPS1) and “I feel cheerful” (HADS3) exhibited the strongest interconnection within the network model. A systematic review found that physical activity during pregnancy can alleviate depressive symptoms in pregnant women both during pregnancy and after childbirth[50]. Shakeel also found that pregnant women who met physical activity standards during pregnancy exhibited a reduced risk of postpartum depression[51]. Physical activity during pregnancy enhances cardiovascular function, improves vascular contractility and permeability, maintains normal nerve fiber conductivity, stimulates neurotransmitter secretion, and thereby helps alleviate negative emotions[52]. Furthermore, One study suggests that anxiety as a mediator in the relationship between physical activity during pregnancy and blood pressure. Engaging in physical activity during early pregnancy may alleviate anxiety symptoms, thereby contributing to blood pressure stabilization throughout gestation[52].

The global connectivity strength of older pregnant women with prepregnancy overweight and obese was significantly higher than that of younger pregnant women. Older pregnant women typically assume greater household and caregiving responsibilities alongside increased occupational demands, leaving limited time and energy for physical activity participation[53]. As maternal age advances, pregnant women experience a progressive decline in physical function and physical activity capacity. This age-related physiological deterioration manifests in diminished physical activity endurance and an increased propensity for discomfort symptoms, including tiredness, lower back pain, and peripheral edema, ultimately resulting in reduced physical activity tolerance[54]. Older primiparous women who reduce their physical activity due to concerns about miscarriage are significantly more likely to experience insufficient physical activity. Furthermore, advanced maternal age is associated with a higher incidence of pregnancy-related complications. These morbidities inherently restrict physical activity, while excessive anxiety regarding fetal preservation further compounds this reduction[55]. Older pregnant women experience more pronounced fluctuations in estrogen and progesterone levels, coupled with age-related decline in neurotransmitter regulation, which increases their vulnerability to low mood.

This study has several limitations. Firstly, as a cross-sectional study, we could not establish causal relationships. Future research should employ longitudinal designs tracking the entire pregnancy trajectory, with assessments stratified by trimester (early, middle, and late) to examine the dynamic interplay between barriers to physical activity and depression among pregnant women with prepregnancy overweight and obese. Secondly, our findings relied exclusively on self-reported measures without clinical diagnostic validation. Future studies should corroborate these results using standardized clinical assessments to ensure diagnostic accuracy. Thirdly, as the data was collected from two hospitals in Jiangsu Province, the representativeness of the sample was limited; A multi center large sample study will be conducted in the future.

Despite these limitations, this study offers several strengths. To our knowledge, this is the first investigation to apply network analysis to examine the interrelationships between barriers to physical activity and depressive symptoms in pregnant women with prepregnancy overweight or obesity. This study indicates that HADS3 (I feel cheerful), HADS5 (I look forward with enjoyment to things), and BPAPS1 (Pregnancy-related intrapersonal barriers) are the core symptoms within the network of barriers to physical activity and depressive symptoms in pregnant women who were overweight or obese before pregnancy. Furthermore, BPAPS1 (Pregnancy-related intrapersonal barriers), BPAPS3 (Interpersonal barriers), and BPAPS4 (Environmental barriers) emerged as bridge symptoms connecting barriers to physical activity to depressive symptoms in pregnant women with prepregnancy overweight or obesity. These findings provide a theoretical foundation for developing targeted nursing interventions aimed at reducing barriers to physical activity and mental health morbidity among pregnant women with prepregnancy overweight and obesity, ultimately improving maternal and neonatal outcomes.The observed variations in network structure and global strength among pregnant women with prepregnancy overweight and obesity across different age groups underscore the importance of considering age-related differences when designing interventions.

Declarations

Acknowledgement

We thank all participants and staffs at the study sites for their cooperation. We wish to thank the reviewers for their insightful comments and suggestions.

Author contributions

All authors have seen and approved the submitted manuscript. Yiyun Yang: Writing – original draft. Shasha Luo: Writing – original draft. Lei Ding: Formal analysis. Chunjian Shan: Formal analysis. Yu Wang: Methodology. Juan Wang: Writing – review & editing. ZhuZhu: Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no competing interests.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Nanjing Women and Children's Healthcare Hospital(2023KY-119). Written informed consent was obtained from all participants

Funding

This study was supported by Nanjing Health Science and Technology Development Special Funds Program (grant number YKK24142).

Data availability

Data used in this study can be obtained from the first author upon request.

Clinical trial number

not applicable.

References

1. Rachmah Q, Mondal P, Phung H, Ahmed F. Association between overweight/obesity and iron deficiency anaemia among women of reproductive age: a systematic review. Public Health Nutr. 2024;27(1):e176.
2. Global. regional, and national prevalence of adult overweight and obesity, 1990–2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021. Lancet (London England). 2025;405(10481):813–38.

3. Kent L, McGirr M, Eastwood KA. Global trends in prevalence of maternal overweight and obesity: A systematic review and meta-analysis of routinely collected data retrospective cohorts. Int J Popul data Sci. 2024;9(2):2401.
4. World Health Organization. Obesity and overweight 2025, March[Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
5. Wu S, Dong J, Mu X, He M. Prevalence and risk factors of underweight, overweight and obesity in women of reproductive age in China. Chin J Clin Nutr. 2022;30(2):79–86.
6. Almutairi FS, Alsaykhan AM, Almatrood AA. Obesity Prevalence and Its Impact on Maternal and Neonatal Outcomes in Pregnant Women: A Systematic Review. Cureus; 2024.
7. Santos S, Voerman E, Amiano P, Barros H, Beilin LJ, Bergström A, Charles MA, Chatzi L, Chevrier C, Chrousos GP, et al. Impact of maternal body mass index and gestational weight gain on pregnancy complications: an individual participant data meta-analysis of European, North American and Australian cohorts. BJOG: Int J Obstet Gynecol. 2019;126(8):984–95.
8. Xiang C, Sui L, Ding X, Cao M, Li G, Du Z. Maternal adiposity measures and hypertensive disorders of pregnancy: a meta-analysis. BMC Pregnancy Childbirth. 2024;24(1):675.
9. Albrecht M, Worthmann A, Heeren J, Diemert A, Arck PC. Maternal lipids in overweight and obesity: implications for pregnancy outcomes and offspring's body composition. Semin Immunopathol. 2025;47(1):10.
10. Monod C, Kotzaeridi G, Linder T, Yerlikaya-Schatten G, Wegener S, Mosimann B, Henrich W, Tura A, Göbl CS. Maternal overweight and obesity and its association with metabolic changes and fetal overgrowth in the absence of gestational diabetes mellitus: A prospective cohort study. Acta Obstet Gynecol Scand. 2024;103(2):257–65.
11. Zhang W, Zhang L, Xu P, Guo P, Mao M, Zhao R, Feng S. Physical activity levels and influencing factors among pregnant women in China: A systematic review and meta-analysis. Int J Nurs Stud. 2024;158:104841.
12. Dipietro L, Evenson KR, Bloodgood B, Sprow K, Troiano RP, Piercy KL, Vaux-Bjerke A, Powell KE. Benefits of Physical Activity during Pregnancy and Postpartum: An Umbrella Review. Med Sci Sports Exerc. 2019;51(6):1292–302.
13. Zhang L, Wang F, Tashiro S, Liu PJ. Effects of Dietary Approaches and Exercise Interventions on Gestational Diabetes Mellitus: A Systematic Review and Bayesian Network Meta-analysis. Adv Nutr (Bethesda Md). 2024;15(12):100330.
14. Lu C, Dreyfuss JM, Hua T, Wolfs D, Nagel EM, Peña A, Lock EF, Seburg E, Pierce S, Kyere-Davies G et al. Maternal Physical Activity and its Relationship to the Human Milk Metabolome and Infant Body Composition. *The Journal of Clinical Endocrinology & Metabolism* 2025.
15. Chen Y, Ma G, Hu Y, Yang Q, Deavila JM, Zhu MJ, Du M. Effects of Maternal Exercise During Pregnancy on Perinatal Growth and Childhood Obesity Outcomes: A Meta-analysis and Meta-regression. Sports Med (Auckland NZ). 2021;51(11):2329–47.

16. Guillemette L, Hay JL, Kehler DS, Hamm NC, Oldfield C, McGavock JM, Duhamel TA. Exercise in Pregnancy and Children's Cardiometabolic Risk Factors: a Systematic Review and Meta-Analysis. Sports Med - open. 2018;4(1):35.
17. Syed H, Slayman T, DuChene Thoma K. ACOG Committee Opinion 804: Physical Activity and Exercise During Pregnancy and the Postpartum Period. Obstet Gynecol. 2021;137(2):375–6.
18. Amiri-Farahani L, Ahmadi K, Hasanpoor-Azghady SB, Pezaro S. Development and psychometric testing of the 'barriers to physical activity during pregnancy scale' (BPAPS). BMC Public Health. 2021;21(1):1483.
19. Du MC, Ouyang YQ, Nie XF, Huang Y, Redding SR. Effects of physical exercise during pregnancy on maternal and infant outcomes in overweight and obese pregnant women: A meta-analysis. Birth (Berkeley Calif). 2019;46(2):211–21.
20. Banafshe E, Javadifar N, Abbaspoor Z, Karandish M, Ghanbari S. Factors Influencing Weight Management in Pregnant Women with Overweight or Obesity: A Meta-Synthesis of Qualitative Studies. J Acad Nutr Dietetics. 2024;124(8):964–e994961.
21. Sominsky L, O'Hely M, Drummond K, Cao S, Collier F, Dhar P, Loughman A, Dawson S, Tang ML, Mansell T, et al. Pre-pregnancy obesity is associated with greater systemic inflammation and increased risk of antenatal depression. Brain Behav Immun. 2023;113:189–202.
22. Fu X, Wang Y, Zhao F, Cui R, Xie W, Liu Q, Yang W. Shared biological mechanisms of depression and obesity: focus on adipokines and lipokines. Aging. 2023;15(12):5917–50.
23. Karim S, Liu J, Wilcox S, Cai B, Merchant AT. Association Between Physical Activity During Pregnancy and Perinatal Depressive Symptoms in Pregnant Individuals With Overweight and Obesity. Womens Health Issues. 2024;34(1):72–9.
24. Dachew BA, Ayano G, Betts K, Alati R. The impact of pre-pregnancy BMI on maternal depressive and anxiety symptoms during pregnancy and the postpartum period: A systematic review and meta-analysis. J Affect Disord. 2021;281:321–30.
25. Ayen SS, Kasahun AW, Zewdie A. Depression during pregnancy and associated factors among women in Ethiopia: a systematic review and meta-analysis. BMC Pregnancy Childbirth. 2024;24(1):220.
26. Jiang T, Tuxunjiang X, Wumaier G, Li X, Li L. Path analysis of influencing factors for prenatal depressive symptoms in pregnant women. J Affect Disord. 2022;317:397–402.
27. Borchers LR, Dennis EL, King LS, Humphreys KL, Gotlib IH. Prenatal and postnatal depressive symptoms, infant white matter, and toddler behavioral problems. J Affect Disord. 2021;282:465–71.
28. Yahya NFS, Teng N, Das S, Juliana N. Nutrition and physical activity interventions to ameliorate postpartum depression: A scoping review. Asia Pac J Clin Nutr. 2021;30(4):662–74.
29. Singh B, Olds T, Curtis R, Dumuid D, Virgara R, Watson A, Szeto K, O'Connor E, Ferguson T, Eglitis E, et al. Effectiveness of physical activity interventions for improving depression, anxiety and distress: an overview of systematic reviews. Br J Sports Med. 2023;57(18):1203–9.

30. Yang Y, Yan X, Wang Y, He J, Pu C, Shan C, Zhang Y, Zhou H. Translation and validation of the Barriers to Physical Activity during Pregnancy Scale. J Nurs Sci. 2024;39(08):49–53.
31. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta psychiatrica Scandinavica. 1983;67(6):361–70.
32. Leung CM, Ho S, Kan CS, Hung CH, Chen CN. Evaluation of the Chinese version of the Hospital Anxiety and Depression Scale. A cross-cultural perspective. Int J psychosomatics: official publication Int Psychosom Inst. 1993;40(1–4):29–34.
33. Mei X, Du P, Li Y, Mei R, Wang X, Chen Q, Ye Z. Fear of childbirth and sleep quality among pregnant women: a generalized additive model and moderated mediation analysis. BMC Psychiatry. 2023;23(1):931.
34. Wu D, Chen S, Zhong X, Zhang J, Zhao G, Jiang L. Prevalence and factors associated with antenatal depressive symptoms across trimesters: a study of 110,584 pregnant women covered by a mobile app-based screening programme in Shenzhen, China. BMC Pregnancy Childbirth. 2024;24(1):480.
35. Epskamp S, Fried EI. A tutorial on regularized partial correlation networks. Psychol Methods. 2018;23(4):617–34.
36. Epskamp S, Cramer AOJ, Waldorp LJ, Schmittmann VD, Borsboom D. qgraph: Network Visualizations of Relationships in Psychometric Data. J Stat Softw. 2012;48(4):367–71.
37. Opsahl T, Agneessens F, Skvoretz J. Node centrality in weighted networks: Generalizing degree and shortest paths. Social Networks. 2010;32(3):245–51.
38. Borsboom D, Cramer AO. Network analysis: an integrative approach to the structure of psychopathology. Ann Rev Clin Psychol. 2013;9:91–121.
39. Epskamp S, Borsboom D, Fried EI. Estimating psychological networks and their accuracy: A tutorial paper. Behav Res Methods. 2018;50(1):195–212.
40. Mei X, Mei R, Yu J, Chen F, Li S, Liang M, Liu Y, Ye Z. Association between adverse childhood experiences and antenatal depression among pregnant women: A computer-simulated network analysis. J Affect Disord. 2025;391:119960.
41. Liu H, Huang F, Gao Y, Wang M, Lin Q, Kong Y, Zhou R, Zhang C, Chen Y. Network analysis of depression and anxiety symptoms and their associations with cognitive fusion among pregnant women. BMC Psychiatry. 2025;25(1):537.
42. Brunner K, Linder T, Klaritsch P, Tura A, Windsperger K, Göbl C. The Impact of Overweight and Obesity on Pregnancy: A Narrative Review of Physiological Consequences, Risks and Challenges in Prenatal Care, and Early Intervention Strategies. Curr Diab Rep. 2025;25(1):30.
43. Suberu F, Adeoye IA. Barriers, attitudes and perceptions to physical activity among pregnant women in Ibadan, Nigeria and the associated factors: a mixed method study. Reproductive health. 2024;21(1):166.
44. Warburton DER, Bredin SSD. Health benefits of physical activity: a systematic review of current systematic reviews. Curr Opin Cardiol. 2017;32(5):541–56.

45. Faucher MA, Mirabito AM. Pregnant Women with Obesity Have Unique Perceptions About Gestational Weight Gain, Exercise, and Support for Behavior Change. J Midwifery Women's Health. 2020;65(4):529–37.
46. Ahmadi K, Amiri-Farahani L, Haghani S, Hasanpoor-Azghady SB, Pezaro S. Exploring the intensity, barriers and correlates of physical activity In Iranian pregnant women: a cross-sectional study. BMJ open sport Exerc Med. 2021;7(4):e001020.
47. Koleilat M, Vargas N, vanTwist V, Kodjebacheva GD. Perceived barriers to and suggested interventions for physical activity during pregnancy among participants of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) in Southern California. BMC Pregnancy Childbirth. 2021;21(1):69.
48. Flannery C, Fredrix M, Olander EK, McAuliffe FM, Byrne M, Kearney PM. Effectiveness of physical activity interventions for overweight and obesity during pregnancy: a systematic review of the content of behaviour change interventions. Int J Behav Nutr Phys Act. 2019;16(1):97.
49. Choi J, Lee M, Lee JK, Kang D, Choi JY. Correlates associated with participation in physical activity among adults: a systematic review of reviews and update. BMC Public Health. 2017;17(1):356.
50. Davenport MH, McCurdy AP, Mottola MF, Skow RJ, Meah VL, Poitras VJ, Jaramillo Garcia A, Gray CE, Barrowman N, Riske L, et al. Impact of prenatal exercise on both prenatal and postnatal anxiety and depressive symptoms: a systematic review and meta-analysis. Br J Sports Med. 2018;52(21):1376–85.
51. Shakeel N, Richardsen KR, Martinsen EW, Eberhard-Gran M, Slinning K, Jenum AK. Physical activity in pregnancy and postpartum depressive symptoms in a multiethnic cohort. J Affect Disord. 2018;236:93–100.
52. Yan W, Wang X, Kuang H, Chen Y, Baktash MB, Eskenazi B, Ye L, Fang K, Xia Y. Physical activity and blood pressure during pregnancy: Mediation by anxiety symptoms. J Affect Disord. 2020;264:376–82.
53. Harrison AL, Taylor NF, Shields N, Frawley HC. Attitudes, barriers and enablers to physical activity in pregnant women: a systematic review. J physiotherapy. 2018;64(1):24–32.
54. Davenport MH, Skow RJ, Steinback CD. Maternal Responses to Aerobic Exercise in Pregnancy. Clin Obstet Gynecol. 2016;59(3):541–51.
55. Das A, Sarkar A, Konar L, Mukherjee B, Das R, Samal SS, Medhavi KK, Lanjewar P. A Study on Feto-Maternal Outcome Among Elderly Pregnant Women During the Intrapartum and Postpartum Period in a Tertiary Care Center. Cureus. 2025;17(4):e82410.

Figures

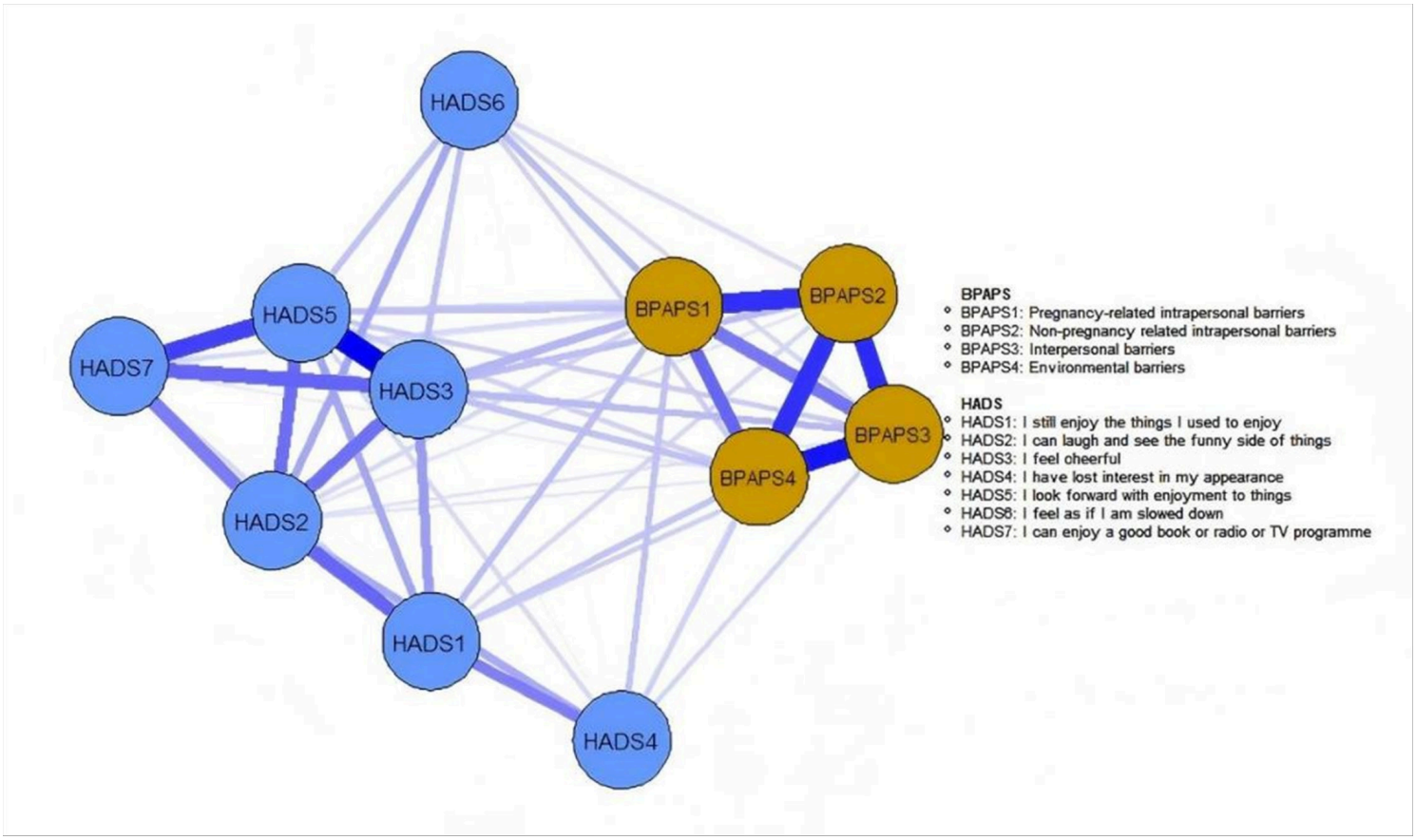


Figure 1

Network structure of barriers to physical activity and depressive symptoms in disabled elderly.

Note: Blue edges represent positive associations.

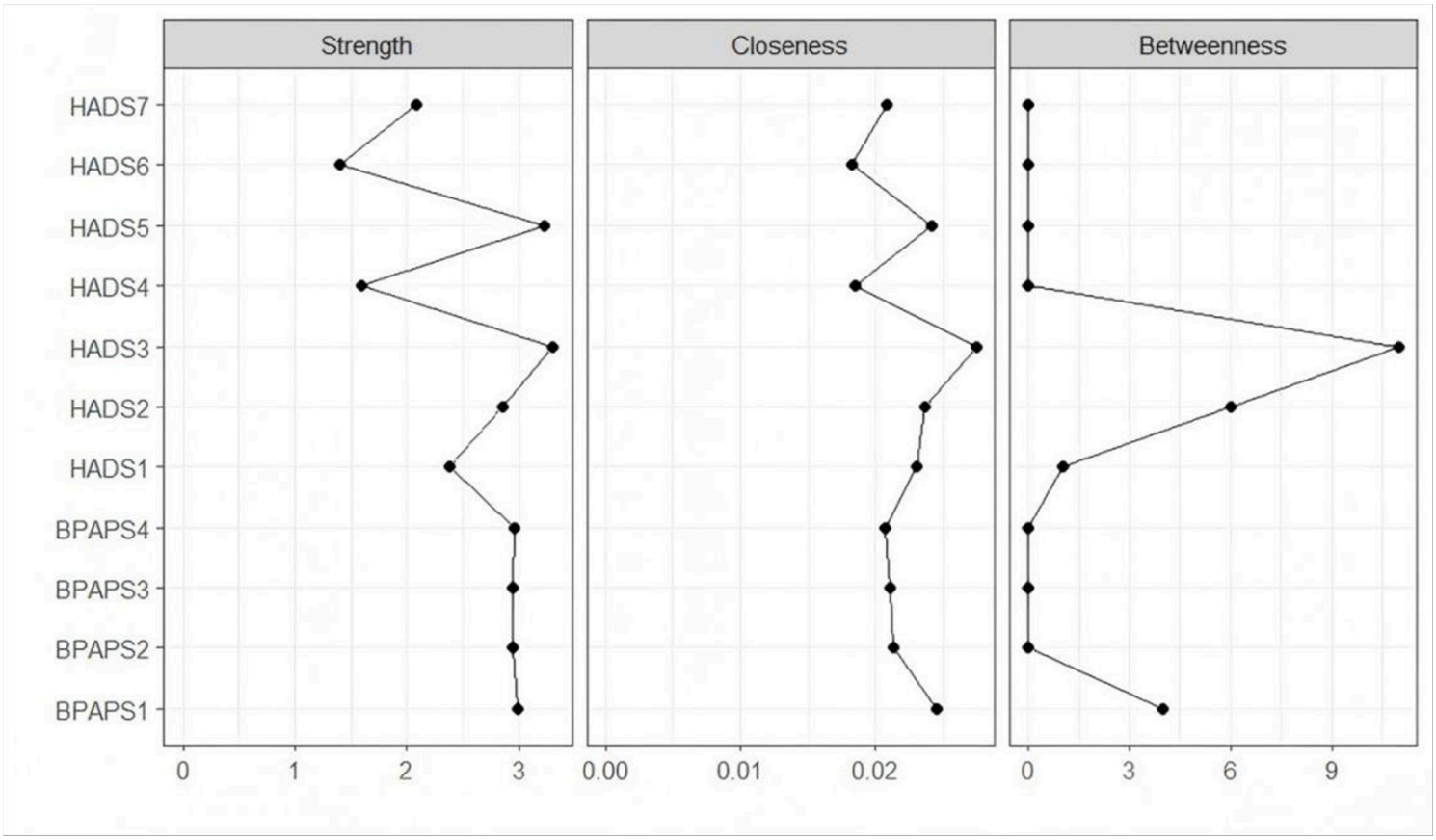


Figure 2

Centrality Indices of all symptoms within the network

Note: BPAPS: Barriers to Physical Activity during Pregnancy Scale; HADS: Hospital Anxiety and Depression Scale.

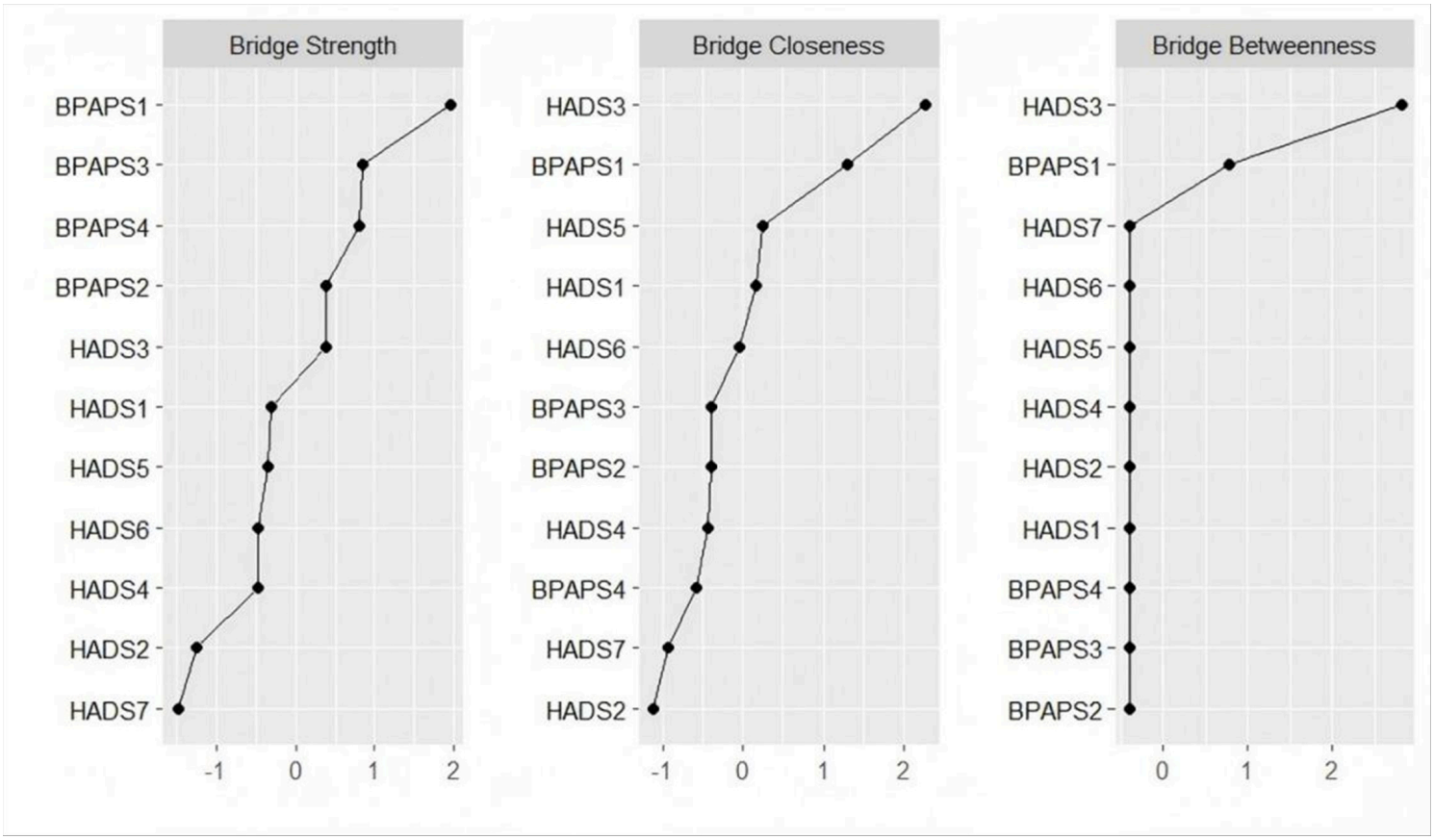
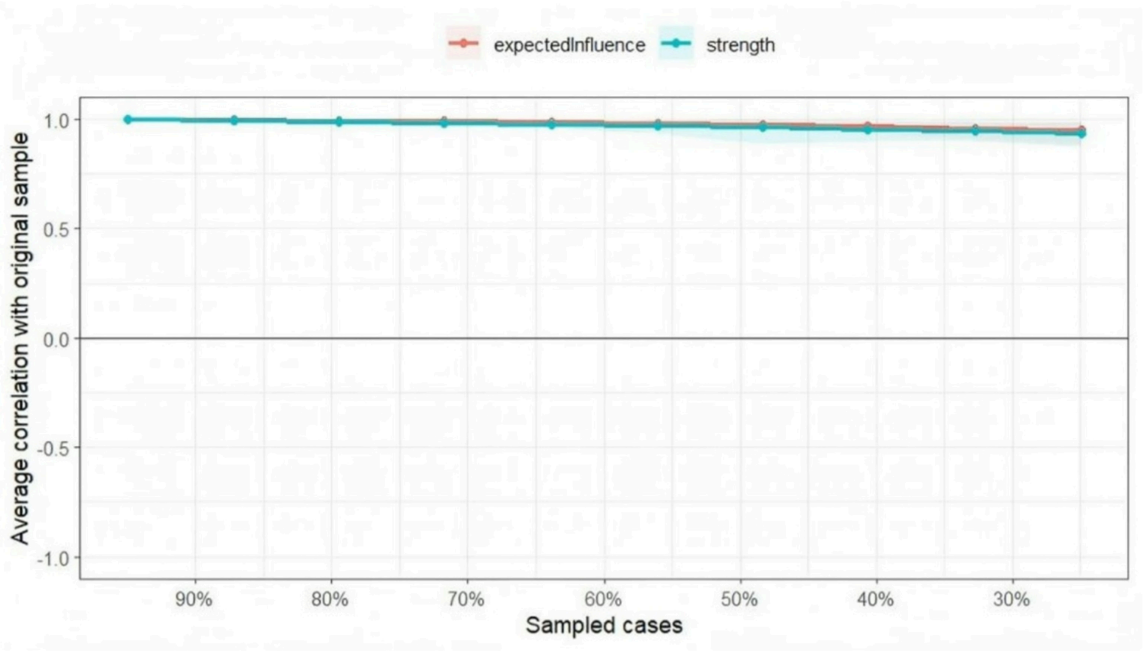


Figure 3

Bridge Centrality Index of all symptoms within the network

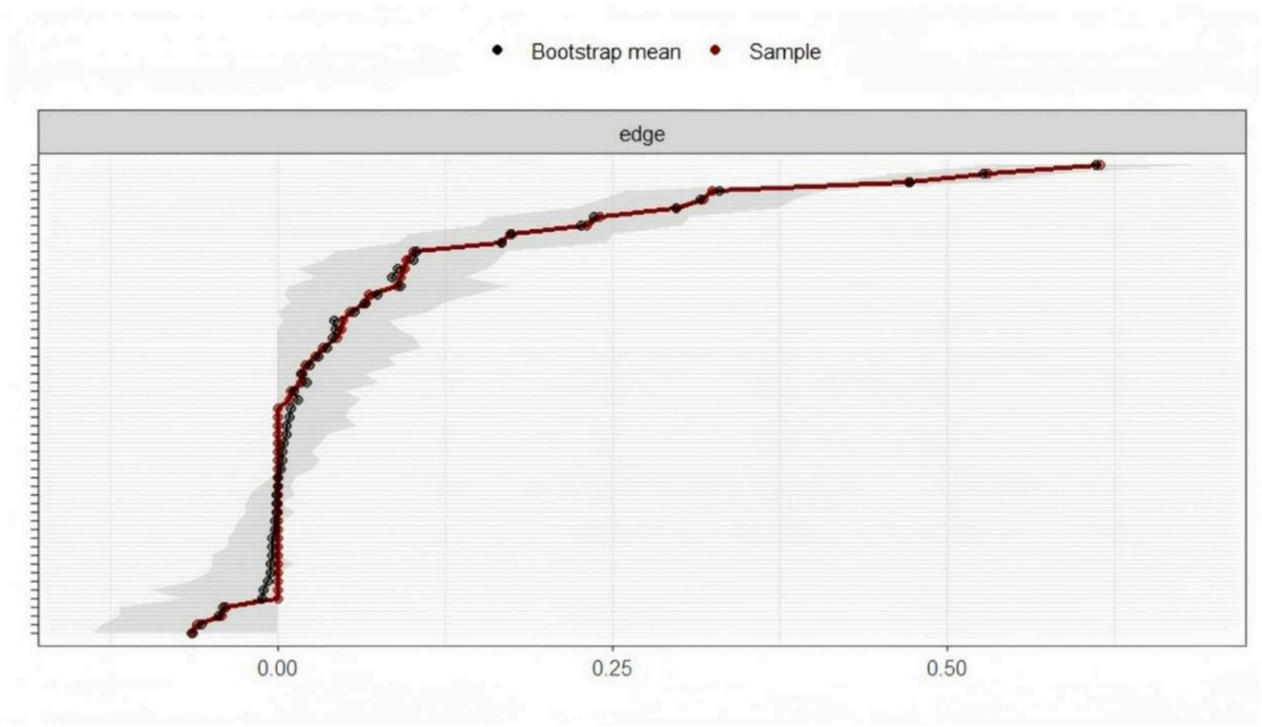
Note: BPAPS: Barriers to Physical Activity during Pregnancy Scale; HADS: Hospital Anxiety and Depression Scale.



Note. The graph shows the stability of network estimates for pregnant women with prepregnancy overweight and obese guided by declining cases. This was done in a bootstrap sample of 1000. The x-axis represents the proportion of discarded samples, and the y-axis represents the correlation between the original center value and the case-discarded centrality value. The graph shows how the centrality estimate is highly stable, with a very strong correlation with the original sample even after 75% of the sample has been discarded.

Figure 4

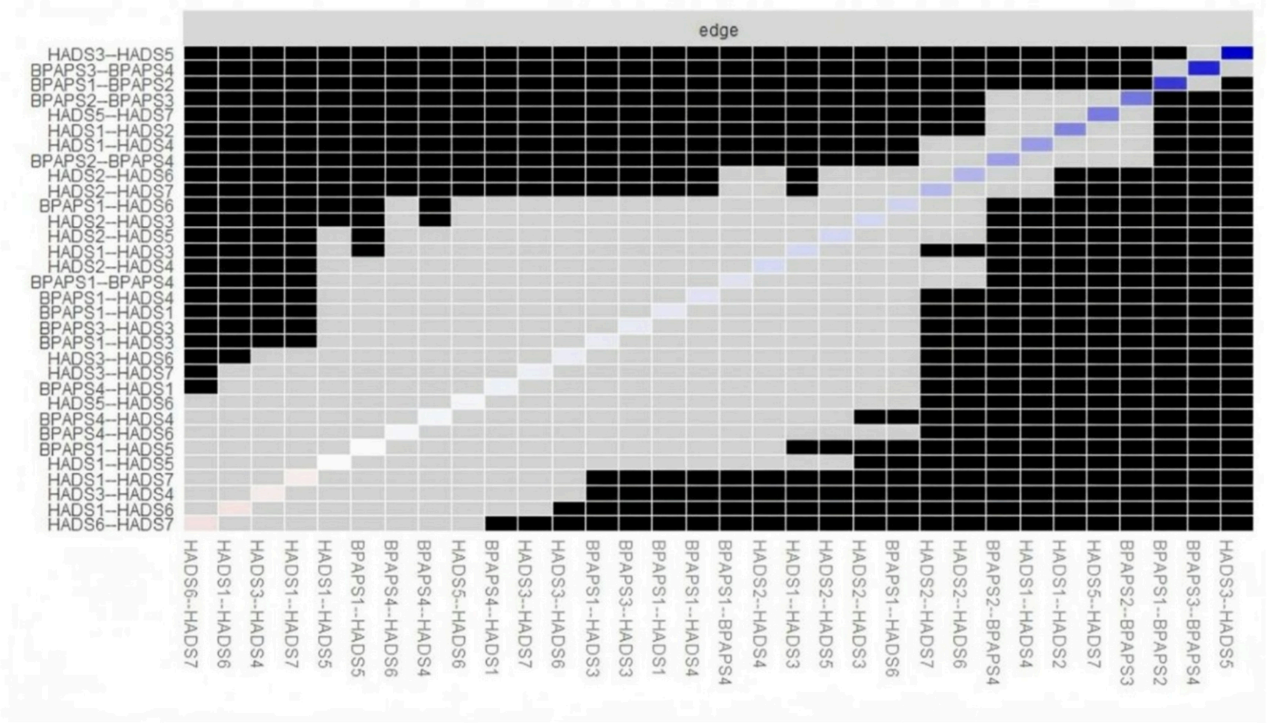
Stability of Centrality Estimates from Case-Dropping Bootstrap



Note. The graph shows the self-bootstrap 95% confidence interval (CI) around the estimated marginal weight/bias correlation coefficient in a network of pregnant women with prepregnancy overweight and obese. The x-axis value represents the edge weight. Each tick on the y-axis represents an edge (labels are removed to avoid clutter), sorted by the estimated edge weights in the sample. The red line represents the sample value (a sample value of 0 indicates that the edges are not included in the network), while the black line represents the average edge weight for 1000 bootstrappers. The gray area indicates the CI of the bootstrapping. The narrower the confidence interval, the more accurate the estimated edge weights.

Figure 5

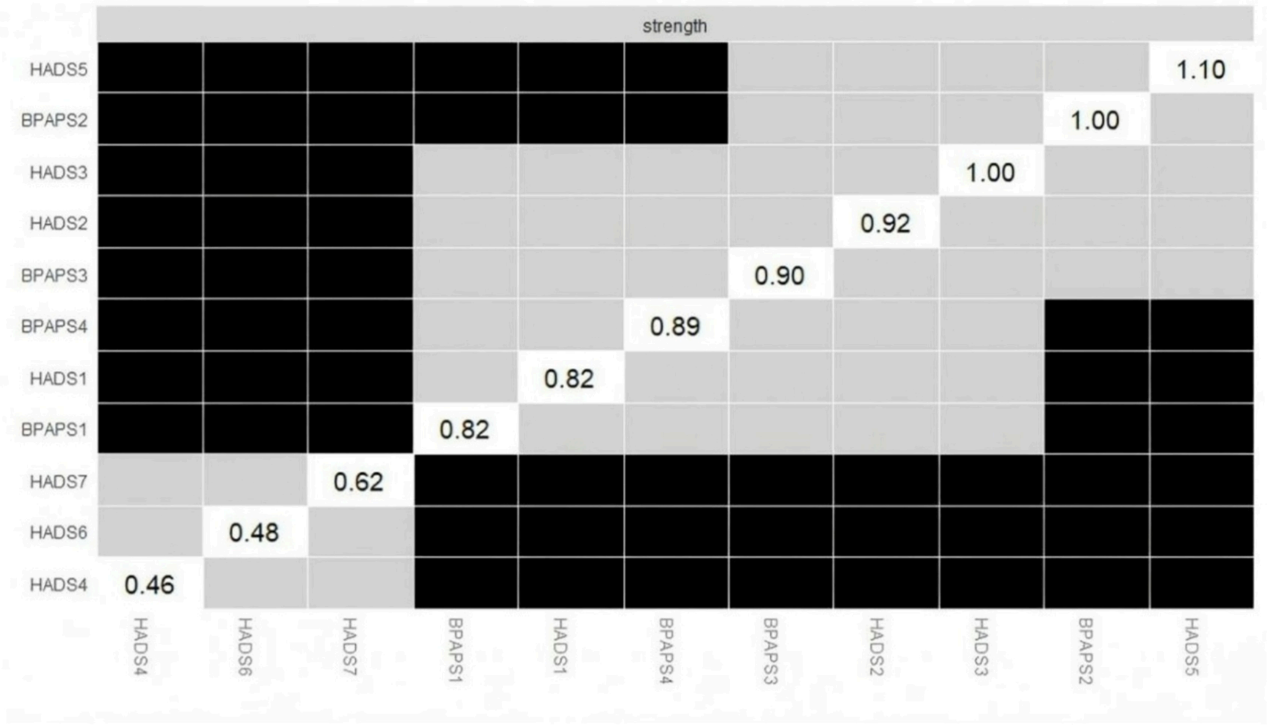
Accuracy of Edge Weights from Non-Parametric Bootstrap



Note. Bootstrap difference test between edge weights in the network. Gray boxes indicate edges that are not significantly different from each other. The black boxes represent edges that are significantly different from each other ($\alpha = 0.05$). The blue box in the edge weight map indicates a positive correlation.

Figure 6

Estimation of Edge Weight Difference by Bootstrapped Difference Test



Note. The graph shows the results of the bootstrap difference test between marginal weights estimated to be non-zero in symptom networks. The black cell indicates a significant difference between the two corresponding edge weights at $p<0.05$. Gray cells indicate a non-significant difference.

Figure 7

Significant Differences Between Edges