General Psychiatry

Social-ecological perspective on the suicidal behaviour factors of early adolescents in China: a network analysis

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ABSTRACT

Background In early adolescence, youth are highly prone to suicidal behaviours. Identifying modifiable risk factors during this critical phase is a priority to inform effective suicide prevention strategies.

Aims To explore the risk and protective factors of suicidal behaviours (ie, suicidal ideation, plans and attempts) in early adolescence in China using a social-ecological perspective.

Methods Using data from the cross-sectional project 'Healthy and Risky Behaviours Among Middle School Students in Anhui Province, China', stratified random cluster sampling was used to select 5724 middle school students who had completed self-report questionnaires in November 2020. Network analysis was employed to examine the correlates of suicidal ideation, plans and attempts at four levels, namely individual (sex, academic performance, serious physical illness/disability, history of self-harm, depression, impulsivity, sleep problems, resilience), family (family economic status, relationship with mother, relationship with father, family violence, childhood abuse, parental mental illness), school (relationship with teachers, relationship with classmates, school-bullying victimisation and perpetration) and social (social support, satisfaction with society).

Results In total, 37.9%, 19.0% and 5.5% of the students reported suicidal ideation, plans and attempts in the past 6 months, respectively. The estimated network revealed that suicidal ideation, plans and attempts were collectively associated with a history of self-harm, sleep problems, childhood abuse, school bullying and victimisation. Centrality analysis indicated that the most influential nodes in the network were history of self-harm and childhood abuse. Notably, the network also showed unique correlates of suicidal ideation (sex, weight=0.60; impulsivity, weight=0.24; family violence, weight=0.17; relationship with teachers, weight=−0.03; school-bullying perpetration, weight=0.22), suicidal plans (social support, weight=−0.15) and suicidal attempts (relationship with mother, weight=−0.10; parental mental illness, weight=0.61).

Conclusions This study identified the correlates of suicidal ideation, plans and attempts, and provided practical implications for suicide prevention for young adolescents in China. Firstly, this study highlighted the importance of joint interventions across multiple departments. Secondly, the common risk factors of suicidal ideation, plans and attempts were elucidated. Thirdly, this

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Early adolescence is a critical stage of human development. Suicidal behaviours increase substantially during this phase. Identifying the correlates of suicidal behaviours for this age group is a priority for informing suicide intervention strategies.

⇒ Previous studies explored the correlates of suicide based mainly on multivariate regression analysis. Little is known about the application of the social-ecological framework to understand these correlates using network analysis.

WHAT THIS STUDY ADDS

⇒ The progression from suicide ideation to suicide attempts is a distinct phenomenon with distinct predictors.

⇒ Multiple social-ecological factors are used to explore the risk and protective factors of suicidal behaviours in early adolescents in China.

⇒ Network analysis of expanded suicide-related factors provides valuable insights and new theoretical directions for adolescent suicide prevention.
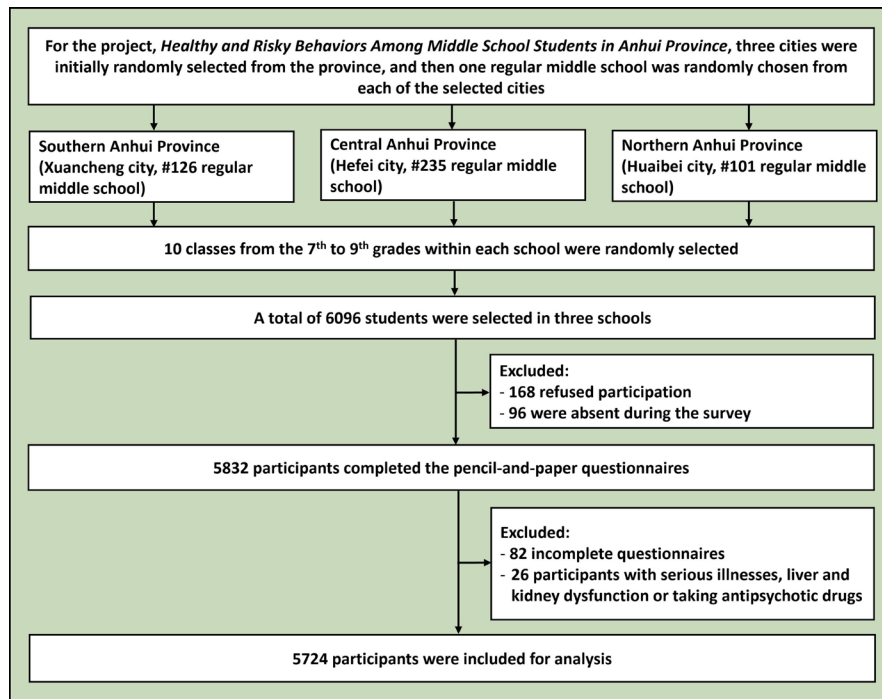
HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study emphasises that future research should focus on the unique influencing factors of suicidal ideation, plans and attempts for targeted interventions.

⇒ This study underscores interventions based on the common risk factors of suicidal ideation, plans and attempts within the social-ecological framework.

⇒ This study highlights the importance of joint interventions across multiple sectors when implementing suicide intervention strategies.

study proposed target interventions to address the unique influencing factors of suicidal ideation, plans and attempts.

INTRODUCTION

Adolescent suicide is a major global public health issue. According to the United Nations International Children's Emergency Fund, suicide is the fifth leading cause of death among adolescents aged 10–19 years worldwide.[1] Suicidal behaviours, including suicidal

For the project, *Healthy and Risky Behaviors Among Middle School Students in Anhui Province*, three cities were initially randomly selected from the province, and then one regular middle school was randomly chosen from each of the selected cities

Southern Anhui Province (Xuancheng city, #126 regular middle school)

Central Anhui Province (Hefei city, #235 regular middle school)

Northern Anhui Province (Huaibei city, #101 regular middle school)

10 classes from the 7th to 9th grades within each school were randomly selected

A total of 6096 students were selected in three schools

Excluded:
- 168 refused participation
- 96 were absent during the survey

5832 participants completed the pencil-and-paper questionnaires

Excluded:
- 82 incomplete questionnaires
- 26 participants with serious illnesses, liver and kidney dysfunction or taking antipsychotic drugs

5724 participants were included for analysis

Figure 1 Flowchart of the participant selection.

ideation (SI), suicidal plans (SP) and suicidal attempts (SA), are the immediate precursors of suicide.[2] The Global School-based Health Survey covering 83 countries reported that the overall prevalence of SI, SP and SA in adolescents aged 12–15 years was 16.5%, 16.5% and 16.4%, respectively.[3] In China, although evidence indicates that the suicide rate has been declining over the past decade, the suicide rate among adolescents remains high—1.5 times higher than the global average for this age group.[4] Notably, while relatively rare before the age of 10, suicidal behaviours increase substantially during early adolescence (ie, 10–14 years old).[5] Early adolescence is a critical transitional period in human development involving major biological, emotional, cognitive, psychological and behavioural changes.[6] Thus, vulnerable adolescents are more prone to psychological and behavioural problems during this period. Suicide not only results in loss of life but also imposes substantial psychological burdens on the surviving family members and friends, such as prolonged grief, shock, anger, guilt, depression, anxiety and even suicidal thoughts, thereby contributing to a considerable financial toll on society.[7] Thus, identifying modifiable risk factors is a priority to inform the development of effective suicide prevention and intervention strategies, especially during early adolescence.

Increasing evidence indicates that suicide is a complex phenomenon influenced by several interacting factors, including social, psychological, cultural, biological and environmental factors.[8] The proposed social-ecological model could provide an ideal framework for a comprehensive understanding of the correlates of suicidal behaviours.[9] The model includes four tiers, namely individual (eg, personal characteristics, such as demographics, health conditions and others), relationship (eg, direct person-to-person interaction, such as with family members, peers and partners), community (eg, neighbourhood centres, schools, workplaces and healthcare providers) and societal (eg, social and cultural norms, policies and other guiding rules or laws). After a thorough literature review, we summarised some key correlates of suicidal behaviours in children and adolescents at these four tiers (see online supplemental table 1 for details). Due to sociocultural differences, people in East Asia are nurtured by Confucianism and tend to incorporate social and family-centric values, while people in Western cultures are encouraged to express their individual feelings and opinions.[10] Additionally, in China, early adolescence is a period when young people step outside the confines of their homes to gain education in middle schools; notably, these adolescents spend a large proportion of their time in school.[11] Hence, the impact of school environments is crucial to shaping adolescents' mental health. Based on this theoretical framework and considering the Chinese cultural background, we aggregated and categorised the risk and protective factors that might influence suicidal behaviours of early adolescents in China into these four levels: individual, family, school and social (see online supplemental table 2 for the specific correlates). Heretofore, a social-ecological model has not been adequately applied to the phenomenon of suicidal behaviours in early adolescents in China. Our classification will help to holistically explore the influencing factors of suicide from a multilevel perspective.

The use of network analysis in psychology has become increasingly popular in recent years. It is a novel approach for describing multivariate dependency structures, and it can extend the traditional regression methods by enabling the quantification and visualisation of the interactions

Table 1 Description of the sample characteristics (N=5724)

Variables		n (%)
Gender	Boy	3006 (52.5)
	Girl	2718 (47.5)
Grade	Grade 7	2011 (35.1)
	Grade 8	1946 (34.0)
	Grade 9	1767 (30.9)
Only child	Yes	1942 (33.9)
	No	3782 (66.1)
Family structure	Nuclear family	3221 (56.3)
	Single-parent family	833 (14.6)
	Large family	1596 (27.9)
	Others	74 (1.2)
Self-perceived family economic status	Poor	499 (8.7)
	Medium	4277 (74.7)
	Good	948 (16.6)
Relationship with mother	Poor to general	1726 (30.2)
	Good	2573 (45.0)
	Excellent	1425 (24.9)
Relationship with father	Poor to general	2432 (42.5)
	Good	2234 (39.0)
	Excellent	1058 (18.5)
Number of friends	<3	1669 (29.2)
	3–5	2336 (40.8)
	≥6	1719 (30.0)
Suicidal ideation	Yes	2169 (37.9)
	No	3555 (62.1)
Suicidal plans	Yes	1086 (19.0)
	No	4638 (81.0)
Suicidal attempts	Yes	317 (5.5)
	No	5407 (94.5)

between all observed variables in the same network.[12] Furthermore, network analysis enables the computation of variable centrality, revealing the variables most important for the maintenance of the network. This approach provides a new perspective for understanding the correlates of adolescent suicide. However, to our knowledge, no network study has systematically examined the influencing factors of SI, SP and SA in early adolescents in China.

Consequently, we primarily used network analysis to explore a range of risk and protective factors of SI, SP and SA at the individual, family, school and social levels in a sample of early adolescents in China. This study provided valuable insights for the development of practical adolescent suicide prevention and intervention strategies.

METHODS
Study design and participants
The data were obtained from the cross-sectional project 'Healthy and Risky Behaviours Among Middle School Students in Anhui Province, China,' which investigated the prevalence and correlates of mental health problems in early adolescents. The project employed a stratified random cluster sampling approach to select participants from Anhui Province and was conducted in November 2020. First, according to geographical location, Anhui Province was divided into three regions: southern, central and northern Anhui, and one city was randomly selected from each region, namely, Xuancheng, Hefei and Huaibei. Second, one regular middle school was randomly chosen from each of the selected cities. Subsequently, 10 target classes from the seventh to ninth grades within each school were randomly selected for the questionnaire survey.

With the assistance of the teachers in each class, we distributed the questionnaires, explained the purpose of this survey and obtained written informed consent from the participants, their parents and teachers. All included students completed an anonymous questionnaire independently, and all questionnaires were collected on the spot. A total of 5832 students were invited to participate in this study. After excluding ineligible students (eg, suffering from serious illnesses, liver and kidney dysfunction or taking antipsychotic drugs) and incomplete questionnaires, we had a final sample of 5724 students (response rate: 98.1%). Figure 1 shows the study flowchart. The schools from the three cities accounted for 35.8%, 30.4% and 33.8% of the valid questionnaires, respectively. Among those with valid responses, 3006 (52.5%) were boys, 2718 (47.5%) were girls, and the mean age was 13.5±1.0 years.

Measurements
Suicidal behaviours
We used three items to assess suicidal behaviours in the past 6 months. The questions were "Have you ever thought about killing yourself in the past 6 months (SI)?"; "Have you ever planned to end your life in the past 6 months (SP)?"; and "Have you ever attempted to take your own life in the past 6 months (SA)?" Each item was coded as a dichotomous variable: 0=no and 1=yes.

Individual-, family-, school- and social-level variables
Based on the social-ecological model framework, the Chinese cultural background, previous evidence (see online supplemental table 1) and the available measures we collected, we ultimately aggregated four levels of risk and protective factors that might influence suicidal behaviours in early adolescents in China, including individual-level (ie, sex, academic performance, serious physical illness/disability, history of self-harm, depression, impulsivity, sleep problems, resilience), family-level (ie, family economic status, relationship with mother, relationship with father, family violence, childhood abuse, parental mental illness), school-level (ie, relationship with teachers, relationship with classmates, school-bullying victimisation and perpetration) and social-level (ie, social support, satisfaction with society). More detailed information on these variables is available in online supplemental table 3.
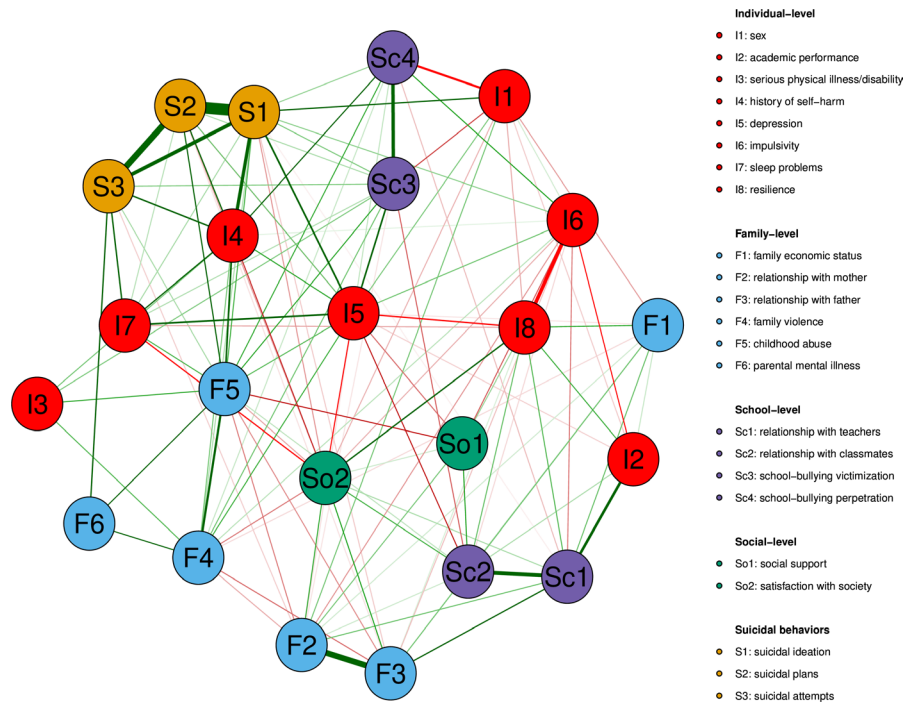
Figure 2 Regularised partial correlation network of suicidal behaviour factors in early adolescents in China. Nodes represent the included variables. The edges connecting the nodes indicate the associations between the nodes, with the green edges representing positive correlations (edge weights >0) and red edges representing negative correlations (edge weights <0). Edge thickness in the graph indicates the strength of associations, with thicker edges representing stronger underlying connections between adjacent nodes.

Statistical analysis

Descriptive analysis

The statistical analysis was performed using SPSS for Windows (V.23.0; SPSS, Chicago, Illinois, USA) and R software (V.4.0.5; R Foundation, Vienna, Austria). Descriptive statistics were reported for all included correlates and the prevalence of SI, SP and SA. The categorical and numerical variables are presented as the number (%) and mean (SD), respectively. Univariate analyses were conducted using χ^2 tests to explore all possible interactions separately.

Network analysis

Network estimation and visualisation

We used network analysis to explore the potential associations between all the included correlates and SI, SP and SA. We also intended to depict the magnitude of these associations. To avoid false positive edges, the Least Absolute Shrinkage and Selection Operator (LASSO) method was used to shrink the small edges to zero.[13] Moreover, the LASSO regularisation with the Extended Bayesian Information Criterion model selection was performed by setting the tuning parameter of 0.5 as the default to obtain a more stable and easier interpretation of the sparse network.[14] In the visualised networks, nodes represent the included variables. The edges connecting the nodes indicate the associations between the nodes, with the green edges representing positive correlations (edge weights >0) and red edges representing negative correlations (edge weights <0). Edge thickness in the network graph represents the strength of associations, with thicker edges

indicating stronger underlying connections between adjacent nodes. The resulting network was visualised using the Fruchterman-Reingold algorithm[15]—the most correlated nodes were placed in the network's centre, while those with the least associations were placed in the periphery. The network was estimated and visualised using the R package *qgraph*.

Centrality estimation

We performed centrality analyses to examine the importance of each node in the network using the R package *qgraph*. The most commonly used centrality indices are closeness, betweenness and strength.[16] Bringmann *et al*[17] indicated that closeness and betweenness as centrality indices were poorly suited for psychological networks due to their complex assumptions. The current analysis therefore focused solely on strength as a centrality index. Strength centrality was calculated as the sum of absolute edge weights of a node (ie, negative edges are turned into positive edges before summing), which distorts the interpretation if negative edges are present. Given that we computed the expected influence (sum of all edge weights (taking account of the sign of each value) connecting a node to other nodes) of each node in the network. Compared with the commonly studied centrality measures (eg, closeness, betweenness and strength), this indicator is more appropriate for the network has both positive and negative edges. The higher the expected influence, the more important the node is in the network.[16]
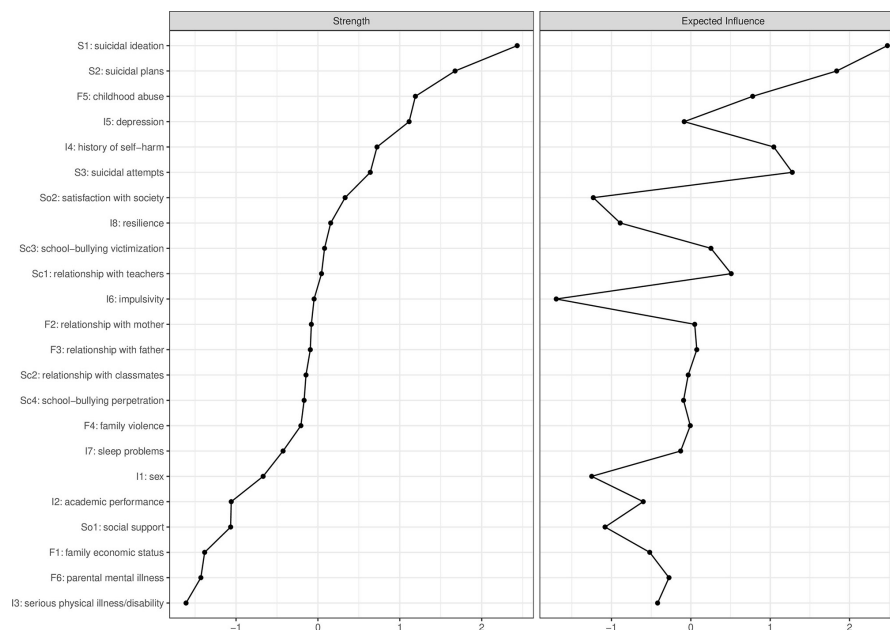
Figure 3 Node-specific centrality indices of suicidal behaviours estimated network. The plot above shows the centrality values for strength (sum of all edge weights (negative edges (edge weights <0) are turned into positive edges (edge weights >0) before summing) connecting a node to other nodes) and the expected influence (sum of all edge weights (taking account of the sign of each value) connecting a node to other nodes). Nodes are listed on the y-axis (suicidal behaviours: S1=suicidal ideation, S2=suicidal plans, S3=suicidal attempts; individual-level: I1=sex, I2=academic performance, I3=serious physical illness/ disability, I4=history of self-harm, I5=depression, I6=impulsivity, I7=sleep problems, I8=resilience; family-level: F1=family economic status, F2=relationship with mother, F3=relationship with father, F4=family violence, F5=childhood abuse, F6=parental mental illness; school-level: Sc1=relationship with teachers, Sc2=relationship with classmates, Sc3=school-bullying victimisation, Sc4=school-bullying perpetration; social-level: So1=social support, So2=satisfaction with society), with their value of centrality on the x-axis. Greater values indicate higher centrality. As negative edges (edge weights <0) are taken into account, the expected influence was found superior in identifying influential nodes within a network graph, compared with the traditional centrality index (eg, strength centrality). The current analysis therefore used the expected influence as a centrality index instead of strength centrality, with higher expected influence corresponding to greater importance of the node in the network.

Accuracy and stability estimation

Using the R package *bootnet*, we tested the accuracy and stability of the estimated network results. The edge weight accuracy was estimated by computing 95% confidence intervals (CIs) around each edge weight through non-parametric bootstrapping using 1000 iterations. A lower overlap between these CIs indicates higher accuracy. Moreover, we used case-drop bootstrapping to calculate the correlation stability (CS) coefficients to determine the stability of the centrality indices. CS coefficients ranged from 0 to 1, where values greater than 0.25 indicated moderate stability, and those greater than 0.5 indicated strong stability.[18]

RESULTS
Descriptive statistics

Table 1 shows the participants' characteristics. Of the 5724 participants (mean age: 13.5, SD: 1.0), 3006 were boys (52.5%). The three grades, 7–9, accounted for 35.1%, 34.0% and 30.9%, respectively. A total of 33.9% of the participants were the only children in their families. A majority (56.3%) had nuclear family structures, and most (74.7%) perceived their family's economic status to be general. More than 30.0% reported a poor relationship with their parents. In contrast, most (70.8%) were actively involved in making friends (more than three friends). Additionally, 37.9%, 19.0% and 5.5% reported SI, SP and SA in the past 6 months, respectively. Among these, 48.6% of the adolescents who had SI developed a specific SP, and 32.6% made an SA; 56.6% of the adolescents with an SP attempted suicide. Online supplemental table 4 shows the distribution of the associated variables of SI, SP and SA. As predicted, there were significant differences (all p<0.001) between SI, SP and SA and all the included factors (sex, academic performance, serious physical illness/disability, history of self-harm, depression, impulsivity, sleep problems, resilience, family economic status, relationship with mother, relationship with father, family violence, childhood abuse, parental mental illness, relationship with teachers, relationship with classmates, school-bullying victimisation and perpetration, social support and satisfaction with society).

Network estimation and visualisation

We included 20 variables in the network model. Figure 2 shows the estimated network of suicidal behaviour factors in early adolescents in China. First, 120 (47.4%) were non-zero among the 253 possible edges; 78 were positive correlations (edge weights >0), and the remaining 42 were negative correlations (edge weights <0). Second, we found 12 edges related to SI, namely sex (weight=0.60), history

of self-harm (weight=1.13), depression (weight=0.71), impulsivity (weight=0.24), sleep problems (weight=0.18), relationship with father (weight=−0.11), family violence (weight=0.17), childhood abuse (weight=0.40), relationship with teachers (weight=−0.03), school-bullying victimisation (weight=0.27), school-bullying perpetration (weight=0.22) and satisfaction with society (weight=−0.22). The eight edges directly connecting SP were history of self-harm (weight=0.57), depression (weight=0.30), sleep problems (weight=0.15), relationship with father (weight=−0.06), childhood abuse (weight=0.56), school-bullying victimisation (weight=0.17), social support (weight=−0.15) and satisfaction with society (weight=−0.20). We found six meaningful edges in SA, namely history of self-harm (weight=0.64), sleep problems (weight=0.62), relationship with mother (weight=−0.10), childhood abuse (weight=0.18), parental mental illness (weight=0.61) and school-bullying victimisation (weight=0.26). SI, SP and SA were collectively associated with a history of self-harm, sleep problems, childhood abuse and school-bullying victimisation. Notably, the network also revealed unique correlates of SI (sex, impulsivity, family violence, relationship with teachers, school-bullying perpetration), SP (social support) and SA (relationship with mother, parental mental illness; see online supplemental table 5 for details).

Centrality estimation

Figure 3 and online supplemental table 6 show the results of the centrality analysis. The main factors influencing the regularised partial correlation network were determined by calculating the centrality metrics as history of self-harm and childhood abuse.

Accuracy and stability estimation

The accuracy and stability of the network results were tested. Online supplemental figure 1 shows the bootstrapped 95% CIs for each edge. There are no clear cut-offs yet to interpret these CIs, making the interpretation difficult. In our model, the width of the 95% CIs for edge weights seemed rather large and overlapping. This means that the weights of these edges should be interpreted with caution. Moreover, the result from the stability analysis revealed that the CS coefficient was 0.40, indicating that the strength centrality value was moderately stable in the network.

DISCUSSION
Main findings

This study used network analysis to systematically explore the correlates of SI, SP and SA in early adolescents in China from the social-ecological perspective. In total, 37.9%, 19.0% and 5.5% of the participating students reported SI, SP and SA, respectively. These rates are higher than those reported in a previous Chinese cross-sectional study, which showed that the prevalence rates of SI, SP and SA were 22.9%, 10.8% and 4.7%, respectively, in middle school students.[19] In the whole-sample network, we identified the factors of suicidal behaviours at the individual, family, school and social levels

of the ecological systems framework. This indicates that the realisation of suicidal behaviours is not only related to adolescents' individual characteristics but also closely related to their family, school and social environment. This also supports the social-ecological theory that an individual's behaviour is affected by their social environment and their interaction with it, as well as the interaction among several systems that are interconnected between the individual development and the surrounding environment.[20] Therefore, we emphasise the importance of joint interventions across multiple departments when implementing suicide prevention strategies for early adolescents.

Among these associations, a history of self-harm, sleep problems, childhood abuse and school-bullying victimisation were common factors of SI, SP and SA, which have previously been verified as key risk factors for adolescent suicide.[21 22] Researchers found that self-harm is a way of communicating suffering and regulating emotions and thoughts. A higher frequency of self-harm behaviours among participants may indicate the numerous attempts to regulate their emotions and thoughts, which might desensitise adolescents to the pain and fear linked to suicide, potentially enhancing their capability or willingness to engage in suicidal behaviour.[23] Unsurprisingly, sleep problems emerged as a potential risk factor for suicidal thoughts and behaviours in adolescents. Previous literature indicated that adolescents who experience sleep problems display worsened mood, increased emotional reactivity to negative stimuli and significant difficulties with emotion regulation (eg, use of ineffective strategies, such as suppression, avoidance and rumination), which in turn could lead to more suicidal behaviours.[24] As previously noted, we also found an important association between childhood maltreatment and suicidal behaviours.[25] Childhood maltreatment is associated with the increased responsiveness of the hypothalamic–pituitary–adrenal (HPA) axis; if the HPA axis is excessively activated, the immune, cardiovascular and endocrine systems are potentially exposed to excessive demands that could lead to dysregulation of these systems over time, thereby increasing the risk of suicide.[26] Moreover, adolescents who experienced bullying might be more likely to attempt suicide due to associated feelings of perceived lack of belongingness, hopelessness and isolation. Consequently, they develop less satisfying social networks and interactions with others, aligning with the interpersonal theory of suicide.[27] Therefore, interventions focusing on these key risk factors may effectively reduce suicidal behaviours in adolescents.

Notably, the network also showed the unique correlates of SI, SP and SA. This result resonates with the ideation-to-action framework proposed by Klonsky and May,[28] which suggested that the progression from SI to SP is a distinct phenomenon with distinct predictors. Thus, the differentiation between SI, SP and SA is vital to identifying youth at risk of death by suicide. Additionally, we found that 48.6% of ideators progressed to formulating a suicide plan and 32.6% made an attempt. Approximately 56.6% of adolescents with a plan attempted suicide. The rates were

similar to those reported in a previous survey of 10 148 adolescents.[29] Suicide behaviours are a gradual development process from SI, SP and SA to suicidal death, with SI being the earliest stage of suicidal behaviours, frequently preceding SP, SA and death by suicide.[30] Therefore, preventive measures targeting the unique influencing factors of SI, SP and SA might be of particular importance, which may stem the progression from SI to concrete SP or SA, thereby reducing adolescent suicide risk.

Limitations

This study had some limitations. First, this is a cross-sectional study. Therefore, the causal explanation is limited. Future studies should examine the direction of effects using longitudinal network models. Second, the measured variables were assessed by self-reports. Thus, recall bias is unavoidable. Third, the risk and protective factors explored in this study are far from exhaustive. Future research should explore more suicide correlates that may influence the network structure. Fourth, as a cross-sectional study, the validation of network analysis in a replicated sample was lacking. Future studies could construct longitudinal network analysis models in cohort studies to further evaluate network replicability. Finally, since the survey was conducted in Anhui Province, China, it is unclear whether these findings can be generalised to broader populations.

Implications

This study examined the possible correlates of suicidal behaviours from the social-ecological perspective using network analysis. It thus provides novel insights into suicide prevention and intervention for early adolescents in China. First, it highlights the importance of joint interventions across multiple departments. Second, it focuses on the common risk factors for SI, SP and SA. Third, it draws attention to the unique influencing factors of SI, SP and SA for targeting interventions.

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