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Research article

The relationship between anxiety and depression in adolescent depression patients: The mediating effect of hope level and coping modes

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ABSTRACT

Background: Adolescents diagnosed with depression are particularly susceptible to anxiety and depressive symptoms, this vulnerability often diminishes their future expectations and overall outlook on life. The objective of this research was to scrutinize the associated risk factors of adolescent depression and delineated the interplay between anxiety and depressive symptoms. Concurrently, it sought to ascertain the latent mediating effects of hope levels and coping strategies within this framework.

Methods: A mixed-methods research approach was employed. For the qualitative component, 18 adolescents with depression were interviewed following a semi-structured interview guide, with sessions audio-recorded. The data were subsequently transcribed and subjected to thematic content analysis. In the quantitative phase, a cross-sectional online survey was administered to 210 adolescents diagnosed with depression using Questionnaire Star, with data analysis performed using SPSS25.0 and AMOS 24.0.

Results: The qualitative analysis identified three major themes and nine categories as key risk factors influencing the onset of adolescent depression. Three major themes were generated: school factors, family factors, and other factors. Nine categories were generated: heavy academic load, strained peer, and teacher-student relationships; unstable family structures, internal familial conflicts, and high parental expectations; a strong sense of social isolation, insufficient sexual education, and prevalent suicidal ideation or attempts. A nurturing and supportive school environment significantly bolsters adolescents' sense of hope and coping abilities, while a warm and encouraging family setting effectively mitigates psychological stress. Conversely, heightened loneliness and the onset of suicidal ideation are frequently linked to diminished hope and the adoption of maladaptive coping strategies. Hence, to comprehensively understand the intricate interplay of these factors, this study concentrated on the levels of hope and coping mechanisms, investigating their potential mediating role in adolescent anxiety and depression. Quantitative analysis revealed a positive correlation between anxiety and depression ($r = 0.767$, $p < 0.01$). Additionally, it was found that hope levels and coping strategies mediated the relationship

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between anxiety and depressive symptoms ($\beta = -0.24$–$0.84 = 0.20$, $p < 0.001$; $\beta = 0.19$–$0.51 = -0.10$, $p < 0.01$), with the mediating influence of hope levels being more significant than that of coping strategies.

Conclusion: Enhancing hope levels and fostering positive coping strategies are instrumental in aiding adolescents with depression to alleviate their anxiety and depressive symptoms. Moreover, this study underscored the importance of focusing on adolescents' mental health and providing them with emotional support, thereby increasing their hope levels and encouraging the adoption of positive coping mechanisms to effectively address their challenges.

1. Introduction

Depression manifests as unprovoked and persistent sadness, a pervasive low mood, despair, feelings of worthlessness, and reduced interest in previously enjoyable activities. This condition may result in concentration difficulties, memory impairment, various forms of non-suicidal self-injury, and in severe instances, can pose significant life-threatening risks [1]. Before the COVID-19 pandemic, the prevalence of clinically significant generalized anxiety and depressive symptoms in large adolescent cohorts was approximately 11.6 % [2] and 12.9 % [3], respectively. The prevalence of mental disorders among adolescents appears to have increased during the COVID-19 pandemic. Specifically, the rates of clinically elevated depressive and anxiety symptoms range from 2.2 % [4] to 63.8 % [5] and 1.8 % [4] to 49.5 % [5], respectively. A meta-analysis of Chinese adolescent samples indicates that the prevalence of depression is 24.3 % [6] and that of anxiety is 24.0 % [7]. Evidence suggests that anxiety and depression during adolescence not only inflict substantial distress on individuals and their families but also precipitate a range of adverse outcomes, including academic failure, impaired cognitive function, poor interpersonal relationships, and even suicide [8]. Research has shown that individuals across all age groups are susceptible to depression. Teenagers, much like adults, face a high risk of developing depression [9]. Depression during adolescence is frequently overlooked. Often, both parents and teachers dismiss the adolescence phase as a period of rebellion, normalizing the presence of abnormal emotions. As a result, adolescent depression often does not receive the necessary attention, diagnosis, or treatment in a timely manner, potentially leading to disability and a reduced lifespan in adolescents [10]. Prolonged depression in teenagers can create significant risks for their physical, psychological, and social development into adulthood, thereby impeding their future progress.

Adolescents with depression frequently experience concurrent anxiety [11]. Anxiety and depression share similarities and differences; anxiety predominantly manifests as nervousness and fear, whereas depression is often rooted in sadness. Both conditions affect thinking, sleep, diet, and energy, ranking as the most common mental disorders in adolescents [12]. A survey among European-American teenagers revealed that anxiety symptoms often precede an increase in depression symptoms, suggesting that internalized symptoms in adolescents might escalate the risk of depression due to anxiety-related behaviors [13]. Additional studies have identified social anxiety disorder as a precursor to adolescent depression, significantly influencing adolescents' internalization behaviors [14–16]. Further evidence suggests that anxiety typically precedes the onset of depression [17,18]. Moreover, early intervention for adolescent anxiety can lower the risk of chronic depression and suicidal tendencies later on [19]. Hence, identifying anxiety is crucial for a comprehensive understanding of the psychological condition of adolescents with depression.

Statistically, anxiety disorders and depression exhibit higher prevalence and disability rates compared to other mental disorders, significantly contributing to the global burden of disease [20]. Numerous studies focusing on the relationship between anxiety and depression have identified a close correlation, primarily evident in symptoms rather than the disorders themselves [21]. Specifically, anxiety and depression share a significant overlap and common risk mechanisms. They are prevalent in teenagers, leading to a substantial disease burden, heightened dysfunction, and are predictors of increased suicide risk [22–24]. Furthermore, teenagers exhibiting high levels of anxiety and depression symptoms also report severe physical symptoms and reduced life satisfaction [25,26]. Evidence also suggests that anxiety and depression in adolescence can disrupt memory and attention control [27]. Anxiety and depression are also linked to problematic behaviors in adolescents, including alcohol abuse [28], smoking [29], and Internet addiction [30]. Given these perspectives, it is imperative to delve into the relationship between anxiety and depression in adolescents with depression, aiding in the identification of mental health issues and offering a theoretical basis for targeted interventions.

In summary, adolescent depression is often misconstrued as typical emotional variability, leading to a lack of timely intervention. This oversight not only inflicts considerable distress on individuals and their families but also precipitates severe outcomes such as academic failure, cognitive impairment, poor interpersonal relationships, and even suicide. Hence, an in-depth study of these symptoms is essential for devising effective interventions and enhancing adolescent mental health.

1.1. Anxiety and depression

Currently, the precise mechanisms underlying the comorbidity of anxiety and depression remain unclear. In clinical practice, numerous patients present with comorbid anxiety and depression, posing challenges in diagnosis and treatment, and making it difficult to pinpoint specific symptoms and implement effective coping strategies. Notably, Choi et al.'s Diathesis Anxiety Model sheds light on the relationship between anxiety and depressive comorbidity [31]. Felez-Nobrega et al.'s study revealed that comorbid depression and anxiety are indicative of poorer health status in patients with multiple diseases, particularly noting depression with anxiety symptoms in 47 low- and middle-income countries [11]. The research by Fisher et al. confirmed that the comorbidity of anxiety and depression

can result in cognitive impairment [32]. Grassie et al. [21] concluded that symptoms like negative self-evaluation, a pessimistic view of the future, and repetitive negative thinking significantly impact the comorbidity of depression and anxiety and may serve as targets for treatment. Songco et al.'s study identified significant heterogeneity in the symptoms of anxiety and depression during adolescence, potentially exacerbating or ameliorating adolescents' overall adaptability [33]. In summary, these findings underscore the rationality behind the comorbidity of anxiety and depression. Given the limited response and effectiveness of treatments in adolescents with anxiety and depression, understanding the factors contributing to these conditions is crucial.

It is common knowledge that adolescent anxiety and depression represent a unique demographic characterized by intricate presentations. Studies have demonstrated that anxiety and depression tend to co-occur sequentially or simultaneously [31], and adolescents who experience both of these mental disorders are more likely to harbor suicidal ideation and engage in suicide attempts [34,35], thereby escalating the risk of maladaptive social adjustment. Furthermore, adolescents with comorbid anxiety and depression demonstrate a greater prevalence of negative emotions and exhibit relatively diminished levels of social involvement compared to those solely afflicted with either anxiety or depression [36]. Wasil et al. [37] discovered a correlation between certain symptoms of depression and anxiety and a decline in overall happiness. Sander et al. [38] affirmed that adolescents exhibiting symptoms of anxiety and depression are predisposed to experiencing disordered eating patterns. Additionally, Alaie et al. [39] revealed that adolescent depression, as a manifestation of mental health disorders, contributes to heightened societal welfare burdens in adulthood. In order to validate the aforementioned standpoint, our research further explored the interplay between anxiety and depression among adolescent depression patients, with the objective of facilitating the identification and screening of afflicted adolescents, and delivering tailored psychological healthcare interventions.

1.2. Mediating effect of hope level

Recent years have seen a surge in positive psychology, leading to increased researches focus on patients' psychological well-being. Hope, being a crucial psychological resource, has gained significant attention among researchers. A review examining factors influencing hope in cancer patients during treatment revealed that it is predominantly linked to internal factors and remains unaffected by external influences [40]. Conversely, certain studies present an opposing viewpoint, delving into the role of hope in cancer patients. This review indicates that an individual's level of hope is shaped by inherent personality traits, environmental factors, and is subject to influence from other variables [41]. In a similar vein, a study focusing on the family hope of children and adolescents with chronic diseases emphasizes that hope is externally derived and systematic in nature [42]. Additionally, a review on hope interventions in chronic diseases identified its vital role as a beneficial clinical practice across physiological, psychological, social, and spiritual domains [43]. Overall, despite varying interpretations of hope, there is a consensus on its positive impact. Hope is characterized as a self-regulating mechanism that buffers against general psychological distress, mitigates negative self-evaluation, and influences future planning [44]. Throughout the COVID-19 pandemic, hope has been demonstrated to alleviate symptoms of anxiety and depression in adults [45]. It is noteworthy that the majority of studies predominantly explore the relationship between hope and depression. Significantly, hope has been identified as a protective factor, capable of reducing suicidal tendencies in cancer patients due to despair and depression, and preventing the psychological burden posed by illnesses [46–48]. However, researches on hope's impact on anxiety are limited, with only a few studies clearly demonstrating that changes in hope levels are closely associated with shifts in anxiety symptoms [49,50], though the specific mechanism remains unclear [40]. Thus, investigating the mediating role of hope levels in anxiety and depression symptoms is of substantial importance. Current research indicates that hope is a trait that can be developed, sustained, and enhanced. A heightened level of hope has been found to boost subjective well-being, augment an individual's sense of self-worth, and increase their inclination towards effective coping strategies [51]. Simultaneously, hope plays a crucial role in the treatment and management of health and diseases. It can modulate the impact of healthcare professionals' perceived stress on anxiety and depression [52]. Additionally, hope is viewed as both a direct and indirect determinant of the quality of life in children and adolescents with chronic illnesses [53]. Moreover, hope serves as a significant protective factor against the severity of depression, safeguarding against the detrimental effects of internalized behavioral issues and stressful events [44,54]. For individuals with mental illness, possessing a high level of hope is key to their recovery [55]. Currently, hope has been proven to significantly regulate the psychological well-being of various patient groups, including cancer survivors [56], individuals undergoing hemodialysis [57], patients with systemic lupus erythematosus [58], and those suffering from schizophrenia [59]. Yet, the role of hope in adolescent depression remains underexplored.

1.3. Mediating effect of coping modes

Coping modes refer to the cognitive and behavioral patterns individuals adopt in response to stress and frustration. Functioning as an independent predictor of psychological symptoms, coping modes play a crucial role in regulating the impact of negative emotions [60]. More specifically, coping modes are categorized into positive coping and negative coping. Prior researches have indicated that positive coping modes can enhance patients' adaptability to illnesses and alleviate psychological distress during treatment and recovery [61]. Conversely, negative coping styles are associated with the onset of anxiety and depression, and can heighten the risk of suicidal ideation [62]. For instance, Cheng et al. [63] found that positive coping modes can mitigate job burnout among nurses; Li et al. [64] discovered that such modes can lessen the psychological distress of individuals with insomnia and enhance their sleep quality; Tang et al. [65] identified positive coping modes as a key factor in reducing depression among college students. In contrast, Schou-Bredal et al. [66] observed that a negative coping style is consistently linked to long-term psychological maladjustment in breast cancer survivors. Similarly, Xiao et al. [67] demonstrated that negative coping modes escalate the risk of suicide among migrant

workers in China. Thus, it becomes evident that different coping modes influence problem-solving approaches. Hence, this study aimed to investigate the coping modes employed by adolescents with depression.

1.4. Current study

Prior research has emphasized the rationality behind the prevalence of anxiety and depression, given the limited responsiveness and efficacy of treatments for adolescent anxiety and depression, understanding the contributing factors to these conditions is paramount. In recent years, positive psychology has seen a flourishing development; however, research regarding the influence of hope on anxiety remains scarce. Thus, investigating the mediating role of hope in anxiety and depressive symptoms holds crucial significance. Varied coping mechanisms affect problem-solving methodologies; hence, this study aimed to examine the coping strategies employed by adolescents with depression. By delving deeper into the interplay between anxiety and depression among adolescent depression patients, it will facilitate the identification and screening of adolescents suffering from depression, thereby offering them personalized preventive measures for mental well-being. Initially, this study involved conducting semi-structured in-depth interviews with 18 adolescents diagnosed with depression, primarily aimed at analyzing the risk factors associated with adolescent depression. Subsequently, the study explored the relationship between anxiety and depression in these adolescent patients. Lastly, the study examined the mediating roles of hope levels and coping modes in adolescent depression through a mediation model, leading to the following hypotheses.

Hypothesis 1. There is a positive correlation between anxiety and depression.

Hypothesis 2. Anxiety is inversely related to hope levels.

Hypothesis 3. Hope levels are inversely associated with depression.

Hypothesis 4. Increased levels of anxiety are associated with more negative coping modes.

Hypothesis 5. More negative coping modes correlate with a higher degree of depression.

Hypothesis 6. Hope levels and coping modes moderate the relationship between anxiety and depression.

2. Materials and methods

2.1. Study design, setting, and participants

A mixed-methods approach was utilized in this study's design. Although extensive research has been conducted on the seasonality of depression, there remains considerable debate among experts regarding the existence of seasonal patterns. Nevertheless, results from Överland's systematic review and recent epidemiological studies [68] lend support to the notion of seasonal patterns in depressive symptoms, with episodes peaking in winter and remitting in spring. Consequently, our study was initiated in the winter season. The research was carried out from November 2021 to July 2022. Participants comprised 210 adolescent depression patients hospitalized at the Second Affiliated Hospital of Xinxiang Medical College. Concurrently, 18 patients with adolescent depression underwent qualitative interviews. Inclusion criteria included adherence to the ICD-10 classification and diagnostic criteria for mental and behavioral disorders, specifically a diagnosis of depression [69]; participants were adolescents aged 10–19 years with adequate language communication abilities and no apparent cognitive impairments. No history of neurological disorders (such as illness or head trauma) or behavioral disorders; had been hospitalized for at least six weeks; had been receiving stable treatment for any mental health disorder (including medication or psychotherapy) for at least two months; was able to use a smartphone; informed consent from both the patient and their family. Exclusion criteria encompassed organic mental disorders, schizophrenia, obsessive-compulsive neurosis, and mental disorders induced by psychoactive substances.

During the recruitment process, it was common for adolescents to conceal their mental health issues, making them reluctant to participate in research or disclose depressive symptoms. Additionally, some adolescents might lack awareness of their depressive symptoms and might be hesitant to acknowledge their condition. Given that adolescent participation typically requires parental or guardian consent, family dynamics and attitudes also play a crucial role in their willingness to engage.

To address these challenges and ensure a representative sample, we provided comprehensive education and awareness campaigns about depression to adolescents and their families, fostering understanding and encouraging participation. Beyond our clinical duties, we established trust with adolescents and their families, offering support and empathy, ensuring their voluntary participation while respecting their privacy and confidentiality. Moreover, we offered incentives such as bookmarks and other appealing gifts to motivate them, ensuring their research participation was both positive and meaningful.

Throughout the entire research process, we had consistently ensured participants' informed consent and adhered to ethical standards. Prior to commencing the study, we submitted the research protocol and informed consent form to the relevant hospital ethics committee for review and approval, ensuring compliance with ethical and legal requirements. During participant recruitment, we provided detailed informed consent forms to participants and their families, outlining the research purpose, methods, anticipated benefits, patient rights, confidentiality measures, and confirming their voluntary participation. We arranged interviews with adolescent patients and their families to thoroughly explain the research purpose and procedures, ensuring full comprehension of the study content and their rights. Additionally, we provided opportunities for families and patients to ask questions, ensuring their understanding of all information and addressing any concerns. Following the assurance of full understanding and voluntary

participation from families and patients, informed consent forms were signed. Throughout the study, we maintained ongoing communication with families and patients, keeping them informed of research progress and any potential changes, ensuring their continuous awareness and voluntary participation.

Prior to the interviews, two researchers underwent standardized training and simulation exercises under the supervision of team members, with targeted feedback from the team mentor to identify and address any deficiencies, thus ensuring the interviews' quality and effectiveness. The interviews were semi-structured, following a guide developed by the research team that covered key issues related to the research questions while allowing flexibility for unexplored topics. With participant consent, the interviews were recorded, transcribed, and anonymized. Sampling continued until data saturation was reached at the 18th interview. One researcher led the interview, posing main questions, steering the conversation, and ensuring all relevant topics were covered, while the other took detailed notes, observed non-verbal cues, and managed the recording equipment. Both researchers identified areas for further exploration without interrupting the interview. Post-interview, they discussed key findings and refined their interview strategies. Initial coding was conducted by the first author, with regular discussions with the last author. Final themes and sub-themes were determined through discussions with all authors.

2.2. Ethics

As the study's subjects were minors, informed consent was obtained from both the subjects and their guardians prior to commencing the study. According to the Declaration of Helsinki, the study received approval from the Ethics Committee of Xinxiang Medical College (XYLL—20220,003).

2.3. Qualitative research

The study utilized convenience sampling to recruit participants and carried out face-to-face interviews with 18 adolescents diagnosed with depression. Data were collected using a semi-structured interview methodology. Following the patients' consent, interviews were initiated and recorded. Interviews lasted approximately 20–30 min and were conducted in a quiet clinic or ward within the hospital. Interview Outline: (1) What is your understanding of depression? (2) Can you describe your feelings before and after the onset of your illness? (3) What are your current major concerns and pressures? (4) How has your lifestyle changed before and after the onset of your illness? (5) What do you believe are the causes of your symptoms? (6) What strategies do you employ to manage your symptoms during depressive episodes? (7) What are your aspirations for your future studies and life? (8) What kind of support do you seek from medical professionals?

This study used thematic analysis method to analyze the interview data. After the data collection was completed and the researchers were familiar with the data, the researchers will conduct preliminary coding of the data, find and determine the themes, and name the theme content. The final research theme will be unanimously agreed upon by the researchers.

2.4. Quantitative research

Purposeful sampling was employed for participant recruitment, with a questionnaire survey administered to 210 adolescent depression patients hospitalized between November 2021 and July 2022. Data collection was conducted online using Questionnaire Star software. To safeguard personal privacy, the questionnaire was designed for single-time completion and anonymous submission. This study utilized a self-rating questionnaire comprising five sections: a general information survey, Zung Self-rating Anxiety Scale, Zung Self-rating Depression Scale, Herth Hope Index, and Medical Coping Modes Questionnaire.

2.4.1. General information questionnaire

General Information Questionnaire: A self-designed questionnaire created by the researchers was employed. It included questions on gender, age, education level, nationality, medical expense payment method, and single-parent family status.

2.4.2. Zung Self-Rating Anxiety Scale

The study utilized the Zung Self-Rating Anxiety Scale developed by Zung [70] in 1971, comprising 20 items. Based on the component factor analysis, this scale is categorized into mental anxiety (10 items) and somatic anxiety (10 items). A 4-point Likert scale was used, with a maximum score of 80. Higher scores indicate greater levels of anxiety. In this study, the Cronbach's alpha coefficient for this scale was 0.912, demonstrating its validity at 0.908.

2.4.3. Zung Self-Rating Depression Scale

The study employed the Zung Self-Rating Depression Scale, developed by Zung [71] in 1965, comprising 20 items. Component factor analysis divides the scale into four categories: emotional symptoms (2 items), somatic symptoms (8 items), psychomotor disorders (2 items), and mental disorders (8 items). A 4-point Likert scale was used, totaling 80 points. Higher scores indicate more severe depression. In this study, the Cronbach's alpha coefficient for the scale was 0.904, with a validity of 0.920.

2.4.4. Herth Hope Index

The Herth Hope Index, developed by Herth [69] in 1991 and subsequently validated by Chan et al. known for its high internal consistency and retest reliability, was utilized in this study [72]. Comprising 12 items, this scale is categorized into three dimensions:

taking positive actions (4 items), maintaining a positive attitude towards reality and the future (4 items), and sustaining close relationships with others (4 items). A 4-point Likert scale was employed, resulting in a maximum score of 48 points. Higher scores indicate elevated levels of hope. In this study, the Cronbach's alpha coefficient for the scale was recorded at 0.767, demonstrating its validity at 0.924.

2.4.5. Medical Coping Modes Questionnaire

The study utilized the Chinese version of the Medical Coping Modes Questionnaire, validated by Shen [73], known for its high internal consistency and retest reliability. This scale comprises 20 items, categorized into three dimensions: confronting (8 items), evading (7 items), and surrendering (5 items). A 4-point Likert scale was employed, yielding a total possible score of 80. Higher scores indicate a greater tendency of patients to adopt these coping methods in dealing with their diseases. In this study, the Cronbach's α coefficient of the scale was 0.762, and the validity coefficient was 0.882, indicating excellent reliability and validity of the scale.

2.5. Data analysis

2.5.1. Qualitative research

Post-interview, two researchers transcribed the sessions, extracted salient statements, and independently performed analysis and coding. Discrepancies in codes or themes were recorded and collaboratively discussed. Subsequently, these themes were holistically analyzed and reviewed within the entire data set to achieve consensus.

2.5.2. Quantitative research

Quantitative Research: Statistical analysis was conducted using SPSS25.0 software (a Statistical Package for the Social Sciences). The sample size calculation was based on the statistical calculation method proposed by Xiao Shunzhen, using the measurement scale with the largest number of items as the calculation reference. The maximum number of items in the scale used in this study is 20, and the sample size selected is 5–10 times the maximum number of items. In order to ensure sufficient sample size, a sample loss of 10 %–15 % was calculated, and the final sample size was determined to be 210. Initially, common method bias was assessed using the Harman single factor test. Subsequently, descriptive statistics and correlation analyses were performed. Pearson correlation analysis was utilized to explore the relationships among anxiety, depression, hope levels, and coping modes. Additionally, independent t-tests and one-way ANOVA tests (Bonferroni post-hoc) were employed to determine differences in depression levels across various demographic characteristics. Furthermore, multiple linear regression was applied to assess whether anxiety and hope levels significantly influence the degree of depression in adolescent patients, with $p < 0.05$ deemed as statistically significant. Ultimately, a structural equation model was constructed using AMOS 24.0. A 95 % confidence interval containing zero indicates no significant mediating effect at the 5 % significance level.

3. Results

3.1. Qualitative research

Participants included 9 boys and 9 girls, with an average age of 16. The total interview duration was 447 min, averaging about 24 min per interview. This study identified three main themes, further subdivided into nine categories (as shown in Table 1).

3.1.1. School factors

Our analysis identified that school-related factors potentially contributed to the development of depression in adolescents. And these factors were further classified into three distinct sub-categories. The majority of the students reported experiencing significant

Table 1
The main themes and sub-theme of factors influencing the onset risk of depression in adolescents.

Main themes	Sub-theme	Quotations
School Factors	Heavy academic load	"I'm mainly stressed in my study and can't concentrate …" (N8)
	Strained peer relationships	"I had an argument with my roommates, and they spoke ill of me behind my back …" (N3)
	Strained teacher-student relationships	"After I made a mistake, the teacher showed impatience, which hit me hard …" (N15)
Family factors	Unstable family structures	"My parents argue throughout the day, there are numerous conflicts, and they have been living separately for an extended period …" (N18)
	Internal familial conflicts	"There is a generation gap between my parents and me, leading to frequent verbal conflicts …" (N11)
	High parental expectations	"My parents expect too much from me, always thinking that I can get into a key university …" (N13)
Other factors	A strong sense of social isolation	"After falling ill, I became reluctant to go out, fearing that my neighbors would gossip about me …" (N2)
	Insufficient sexual education	"Having expressed my feelings to a male counterpart and encountered rejection, I underwent a transformation characterized by heightened sensitivity and increased suspicion. …" (N7)
	Prevalent suicidal ideation or attempts	"Following a dispute with my parents, I ingested roughly more than 100 pills …" (N3)

stress, manifesting in poor academic performance, coupled with an excessive workload from homework and frequent examinations. Several students expressed reluctance to attend school due to poor academic performance, with concerns primarily centered around future educational prospects and overwhelming academic pressures, including excessive homework and exams.

> I don't want to go to school because my academic performance is poor … (N2) ; At present, the biggest worry is the problem of entering a higher school. I'm afraid that I won't be admitted to a good university … (N7); I'm mainly stressed in my study and can't concentrate … (N8); There are too many homework and exams in junior high school … (N10).

Additionally, a portion of the students reported feelings of exclusion and isolation following conflicts with classmates. With incidents ranging from verbal backbiting to physical bullying and harassment. Furthermore, a smaller group mentioned experiencing ostracization from their teachers.

> I had an argument with my roommates, and they spoke ill of me behind my back … (N3); I had a quarrel with my classmates, which sometimes affected me … (N6); Some classmates bullied me, hit me with a stool, threw my shoes or shut me in the toilet … (N10); The teacher's attitude towards you is mainly based on academic performance … (N4); The teacher often criticize me, which makes me feel annoyed … (N8); After I made a mistake, the teacher showed impatience, which hit me hard … (N15).

3.1.2. Family factors

Additionally, we identified family-related factors as potential contributors to adolescent depression, categorized into three distinct sub-categories. A number of students highlighted the profound impact of an unstable family structure, Others expressed the immense pressure they felt due to high parental expectations, ranging from rigorous scrutiny of academic performance to expectations of admission into prestigious universities. Furthermore, several students mentioned that family conflicts often led to a loss of emotional control, with reasons varying from frequent parental arguments over household matters to generational differences and persistent marital discord.

> My parents' divorce hit me hard … (N10); My parents are very strict with me. Every time I come home after an exam, they would scrutinize and ask me in great detail about the questions I got wrong … (N5); My parents expect too much from me, always thinking that I can get into a key university … (N13); Parents often quarrel because of family chores … (N1); There is a generation gap between my parents and me, leading to frequent verbal conflicts … (N11); My parents argue throughout the day, there are numerous conflicts, and they have been living separately for an extended period … (N18)

3.1.3. Other factors

In conclusion, we identified that risk factors influencing the onset of adolescent depression might be linked to various other aspects, categorizing them into three subtypes. The majority of students indicated a deficiency in understanding and support, leading to a strong sense of social isolation; A portion of the students had conveyed contemplation and instances of suicidal ideation and attempts; A minority of students, conversely, articulated difficulties in appropriately managing interpersonal dynamics with individuals of the opposite gender.

> After falling ill, I became reluctant to go out, fearing that my neighbors would gossip about me … (N2); I find myself devoid of meaningful companionship, lacking a circle of friends, and feeling a profound sense of solitude with no one who truly comprehends my inner world … (N14); I find myself grappling with the intricacies of interpersonal dynamics among peers, frequently resorting to deliberate avoidance in my interactions with them … (N15); I harbor a reluctance towards socializing with others and am disinclined to partake in collective endeavors … (N17).

A portion of the students had conveyed contemplation and instances of suicidal ideation and attempts. A minority of students, conversely, articulated difficulties in appropriately managing interpersonal dynamics with individuals of the opposite gender.

> Following a dispute with my parents, I ingested roughly more than 100 pills … (N3); I harbor a sense of insignificance, devoid of any lingering attachment to this world … (N10); I contemplate existence as bereft of intrinsic value, enduring intense suffering, and departing represents a form of liberation for me … (N15). Having expressed my feelings to a male counterpart and encountered rejection, I underwent a transformation characterized by heightened sensitivity and increased suspicion.… (N7); The absence of mutual affection from the girl I hold affections for elicits a poignant sense of melancholy within me.… (N9); I found myself entangled in a physical intimacy with my girlfriend, resulting in a compelled dissolution of our relationship, and I am burdened by a profound sense of self-reproach and guilt … (N12); I found myself compelled into an involuntary engagement in a sexual encounter … (N16).

3.2. Quantitative research

3.2.1. General characteristics of participants

The majority of the 210 participants fell within the 13–15 years age bracket, comprising 52.40 % (110 out of 210) of the total sample. Female students represented a larger portion of the sample, at 70.00 % (147 out of 210), significantly outnumbering male students. The participants predominantly belonged to the Han nationality, constituting 98.10 % (206 out of 210) of the total. Furthermore, a substantial number of participants were junior and senior high school students, accounting for 50.50 % (106 out of

210) and 37.60 % (79 out of 210) respectively. Regarding medical expenses, a significant portion, 41.00 % (86 out of 210), were self-financed. The majority of the study participants came from complete family structures, representing 89.00 % (187 out of 210) of the total. These findings were detailed in Table 2.

3.2.2. Descriptive statistics and correlation analysis of anxiety, depression, hope level, and coping modes in adolescents with depression

Table 3 presented the descriptive statistics and correlation analysis of anxiety, depression, hope level, and coping modes among adolescents diagnosed with depression. The mean anxiety score among participants was 45.52 ± 12.27 (out of a total score of 80), suggesting a high level of anxiety in adolescents with depression. The average depression score was 52.36 ± 12.39 (out of a total score of 80), indicating a moderately high level of depression in this cohort. For hope levels, the average score was 30.8 ± 5.95 (out of 48), denoting a relatively high level of hope among these adolescents. The mean score for coping modes stood at 42.10 ± 3.03 (out of 80), the mean score for active coping was 14.93 ± 6.54 (out of a total score of 32), and for passive coping, it was 27.17 ± 8.95 (out of a total score of 48). Furthermore, the percentage of adolescents with depressive symptoms using passive coping was 76.19 %, implying a tendency towards negative coping strategies among these individuals. Additionally, the study revealed a positive correlation between anxiety and depression, whereas both anxiety and depression showed a negative correlation with hope levels. It was observed that higher levels of anxiety and depression were associated with more negative coping mechanisms. Overall, the initial support for assumptions 1–5 of this study was evident (see Table 4).

3.2.3. Univariate analysis of the degree of depression in adolescents with depression: variation across different characteristics

The univariate analysis indicated that the degree of depression among adolescents did not significantly vary across different genders, ages, nationalities, education levels, or in cases of single-parent families. Contrastingly, a statistically significant difference was observed in the depression scores among adolescents when categorized by their methods of medical expense payment. For detailed results, referred to Table 2.

3.2.4. Multiple linear regression analysis of the degree of depression

To further validate Hypotheses 1, 3, and 5, we employed multiple linear regression analysis. Within the constructed models, Model I assessed the influence of control variables on depression, Model II incorporated anxiety as an independent variable in addition to Model I, Model III further included the level of hope based on Model II, and Model IV integrated coping style along with the variables in Model III to evaluate their impact on depression.

The results of Model I ($F = 2.410$, $p < 0.05$, $R^2 = 0.066$) revealed that demographic variables accounted for 6.6 % of the variance in depression, with 'different methods of medical expense payment' being a significant predictor. In Model II ($F = 52.276$, $p < 0.001$, $R^2 = 0.644$), the addition of anxiety as an independent variable rendered 'different methods of medical expense payment' insignificant as a predictor of depression. After controlling for the influence of education level, all variables collectively explained 64.4 % of the variance in depression, with anxiety alone explaining 80 % of this variance. In Model III ($F = 82.042$, $p < 0.001$, $R^2 = 0.766$), anxiety and hope level were added as independent variables, controlling for the confounding effect of education level. These variables together explained 76.6 % of the variance in depression, with hope accounting for 12.1 % of this variance. In Model IV ($F = 75.017$, $p < 0.001$, $R^2 = 0.771$), anxiety, hope level, and coping style were included as independent variables, collectively explaining 77.1 % of the variance in depression, with hope contributing 0.6 % to this variance. Thus, the accuracy of Hypotheses 1, 3, and 5 was confirmed.

3.2.5. The mediating effect of hope level and coping modes on anxiety and depression

Structural equation modeling was employed to examine the mediating roles of hope level and coping modes. Fig. 1 illustrated the mediation path analysis for hope level and coping modes. Results indicated that anxiety directly influenced depression ($\beta = 0.70$, $p < 0.001$) and negatively affected hope level ($\beta = -0.24$, $p < 0.001$). Concurrently, hope level was found to have a direct negative

Table 2
General information of participants and univariate analysis of depression levels.

characteristic		*N* (%)	*p* value
gender	male	63 (30.00)	0.17
	female	147 (70.00)	
Age (years)	aged 10∼12	14 (6.70)	0.94
	aged 13∼15	110 (52.40)	
	aged 16∼19	86 (41.00)	
education level	primary school	13 (6.20)	0.46
	middle school	106 (50.50)	
	high school	79 (37.60)	
	university	12 (5.70)	
modes of medical expense payment	basic medical insurance	81 (38.60)	0.02
	commercial medical insurance	43 (20.50)	
	self funded	86 (41.00)	
nation	han chinese	206 (98.10)	0.82
	other	4 (1.90)	
single-parent family classification	yes	23 (11.00)	0.11
	no	187 (89.00)	

Table 3
Descriptive statistics and correlation analysis of anxiety, depression, hope level, and coping modes in adolescents with depression.

	Anxiety	Depression	Coping modes	Expected level	Positive coping	Negative coping
Anxiety	1.00					
Depression	0.767[a]	1.00				
Coping modes	0.820[a]	0.589[a]	1.00			
Expected level	−0.499[a]	−0.705[a]	−0.375[a]	1.00		
Positive coping	−0.994[a]	−0.776[a]	−0.802[a]	0.511[a]	1.00	
Negative coping	0.991[a]	0.761[a]	0.852[a]	−0.497[a]	−0.988[a]	1.00
Mean	45.52	52.36	42.10	30.80	14.93	27.17
Standard error	12.27	12.39	3.03	5.95	6.54	8.95

Notes.
[a] Correlation is significant at the 0.01 level (2-tailed).

Table 4
Multiple linear regression analysis of the degree of depression.

Variables	Model I	Model II	Model III	Model IV
Constant	40.259	6.462	43.456	59.599
Gender	3.301	0.087	0.122	0.067
Age	−2.092	−0.742	−0.134	0.045
Education level	2.588	2.443[c]	1.907[c]	1.727
Modes of Medical Expense Payment	−2.611[b]	0.058	−0.141	−0.189
Nation	2.538	0.466	0.335	0.641
Single-Parent Family Classification	4.128	2.398	1.562	1.672
Anxiety	/	0.800[a]	0.597[a]	0.694[a]
Hope level	/	/	−0.839[a]	−0.831[a]
Coping modes	/	/	/	−0.500[c]
R 方	0.066	0.644	0.766	0.771
ΔR方	0.066	0.578	0.121	0.006
F	2.410[c]	52.276[a]	82.042[a]	75.017[a]

Notes.
[a] Correlation is significant at the 0.001 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).
[c] Correlation is significant at the 0.05 level (2-tailed).

relationship with depression ($\beta = -0.84$, $p < 0.001$). Furthermore, anxiety was indirectly associated with depression, mediated by hope level ($\beta = -0.24$–$0.84 = 0.20$, $p < 0.001$***). Additionally, anxiety directly influenced depression ($\beta = 0.70$, $p < 0.001$) and negatively affected coping modes ($\beta = 0.19$, $p < 0.001$). Coping modes also exhibited a direct negative relationship with depression ($\beta = -0.51$, $p < 0.05$). Anxiety also showed an indirect relationship with depression, mediated by coping modes ($\beta = 0.19$–$0.51 = -0.10$, $p < 0.01$*). Goodness-of-fit indices were computed to assess the model's fit to the data, as detailed in Table 5. The SEM demonstrated acceptable and significant fit. Upon establishing hope level and coping modes as mediating variables, the significance of the mediation effect warranted further verification. Table 6 reported the standardized total, indirect, and direct effects among anxiety, depression, hope level, and coping modes. The bootstrapped 95 % confidence interval for the indirect effect between anxiety and depression, excluding zero (0.150–0.268 and −0.184 to −0.123), indicated a significant mediation effect of hope level and coping modes on their relationship. The partial mediation effect of hope level and coping modes accounted for 25.28 % (0.202/0.799) and 12.14 % (0.097/0.799) of the total effect, respectively. Consequently, Hypothesis 6 was validated through these findings.

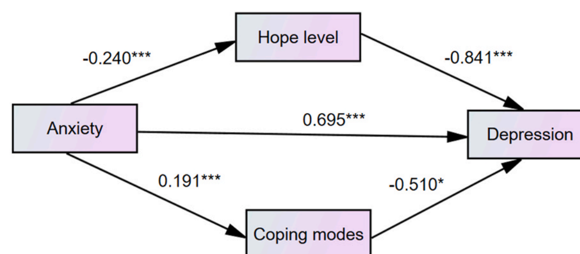

Fig. 1. Pathway of the SEM ($N = 210$) Except for the pathway from coping strategies to depression, which is significant at the 0.05 level, all the path coefficients were unstandardized estimates. ***$P < 0.001$.

Table 5
Model fit ($N = 210$).

Index	χ^2/df	GFI	AGFI	RMSEA	CFI
Depression	0.398	0.999	0.991	0.001	0.999

Abbreviations: χ^2/df, CMIN/degree of freedom; GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; RMSEA, the root mean square error of approximation; CFI, comparative fit index.
All pathway coefficients of SEM were significant at the level of 0.05. A SEM was considered acceptable when χ^2/df was <3; RMSEA was <0.08; and GFI, AGFI, CFI were ≥ 0.90.

Table 6
The standardized total, indirect, and direct effects of mediation model among anxiety, depression, hope level, and coping modes. (N = 210).

			Bootstrap[a]			
			Bias corrected 95 % CI		Percentile 95 % CI	
Model pathway	Point estimate	SE	Lower	Upper	Lower	Upper
Total effect						
Anxiety→Depression	0.799	0.042	0.716	0.883	0.717	0.884
Indirect effect						
Anxiety→Hope level→Depression	0.202	0.030	0.150	0.268	0.146	0.262
Anxiety→Coping modes→Depression	−0.097	0.041	−0.184	−0.023	−0.182	−0.021
Direct effect						
Anxiety→Depression	0.695	0.052	0.596	0.800	0.599	0.802

Notes.
[a] Number of bootstrap samples: 5000.

4. Discussion

This study's findings hold substantial clinical significance. Qualitative analysis revealed that adolescent depression's risk factors were initially linked to the school environment. Key factors within this setting include academic burden, peer exclusion, and conflicts between teachers and students [9,74]. Given that China has enforced nine-year compulsory education since the 1980s, which is somewhat obligatory, it follows that most children and adolescents spend a significant portion of their formative years in schools, where interactions with peers and teachers may naturally lead to friction. Furthermore, academic performance, as a focal point in students' lives, is often pursued diligently by students to meet parental expectations and garner teacher approval, as well as to navigate social competition. Additionally, our research indicated that family dynamics were significant risk factors for adolescent depression. Factors such as unstable family structures and familial conflicts are crucial predictors of mental health issues, antisocial behaviors, and substance abuse in adolescents [75]. The weakened social support, insecurity, and emotional instability experienced by adolescents in dysfunctional families exacerbate intrafamily tensions, significantly impeding their development. Other factors, including social fear, intense feelings of social isolation, and inadequate sexual education, can also misguide adolescents, potentially leading to suicidal ideations or attempts. In light of these findings, future research should concentrate on analyzing external environmental influences, such as school and family dynamics, on adolescent depression.

Through qualitative research, this study had profoundly explored the factors influencing depression in adolescent patients from the interviewees' perspectives, shedding light on the underlying complexity and contextual nuances. By analyzing three major themes—school, family, and other factors—and nine sub-themes, the study had decided to incorporate hope levels and coping mechanisms to further validate and investigate the relevant data concerning adolescent depression.

In quantitative analysis, the study discovered a direct correlation where increased anxiety in adolescents with depression corresponded with more pronounced depressive symptoms and diminished levels of hope, impeding the adoption of positive coping strategies. This finding aligns with similar studies conducted in Western contexts [76]. The rationale behind this is rooted in the significant cognitive and socio-emotional changes occurring in adolescence, marking a transition from dependence to independence. As adolescents work towards solidifying their personal identities and forging complex interpersonal relationships, their exposure to stressful life events increases, potentially resulting in adverse mental health outcomes. Moreover, adolescents grappling with anxiety and depression often experience diminished personal achievements and value in the face of stress and frustration, leading to lower hope levels and adversely affecting their overall quality of life and subjective well-being. Significantly, the trajectory of hope development often undergoes considerable changes during adolescence [77]. In this phase, a high level of hope can motivate adolescents to actively address stress and crises, seek solutions, and mitigate the physical, mental, and social burdens associated with their conditions. Conversely, adolescents with lower hope levels tend to resort to negative coping strategies like avoidance and submission, heightening the risk of emotional disorders. Thus, enhancing the level of hope in adolescents experiencing severe anxiety and depression is crucial, guiding them towards effective coping strategies to confront, rather than evade their challenges.

Our study indicated that the degree of depression in adolescents did not significantly vary across different genders, ages, nationalities, education levels, or based on whether they come from single-parent families. Significantly, we observed differences in depression levels among adolescents based on their methods of medical expense payments, aligning with findings from Chiang et al.

[78]. Adolescents who self-finance their medical expenses exhibited more pronounced depressive symptoms compared to those utilizing medical insurance. This can be attributed, in part, to the lengthy and costly treatment process, imposing a substantial burden on economically disadvantaged families. Additionally, the stigma associated with mental illness plays a role, as prolonged deviation from daily life due to mental illness amplifies social distancing, fears of external prejudice and discrimination, and intensifies social fear and isolation. Crucially, after accounting for socio-demographic factors, anxiety accounted for 59.4 % of the variation in depression levels, and hope level for 12.8 %. This was in line with prior research [79,80] and underscored anxiety and hope level as significant predictors of the degree of depression in adolescents.

This study culminated in the construction of an intermediary model, demonstrating that hope levels and coping strategies mediated the relationship between anxiety and depression in adolescents. Notably, the mediating effect of hope was more pronounced than that of coping modes. Essentially, anxiety influences the severity of depression via the level of hope, corroborating previous research [81] which suggests that heightened hope correlates with improved emotional and behavioral health. The role of hope in adolescents cannot be overstated. Hope aids in setting personal goals and planning, fosters positive future-oriented thoughts, and mitigates the emotional distress associated with stress. Additionally, the significance of hope has been highlighted in other studies. For instance, bolstering hope has been found to relieve anxiety and depression in adults during COVID-19 lockdowns [45], enhance life quality in colorectal cancer patients [82], and lessen the adverse effects of disease uncertainty in systemic lupus erythematosus patients [58]. Hope serves as a positive coping resource amidst adversities. Viewed through the lens of positive psychology, hope not only enhances overall well-being but also fosters social support and mental resilience, aiding in individual recovery. In summary, our findings underscored the beneficial impact of hope. Future research endeavors should delve into the dynamic evolution of hope in adolescents with depression and develop stage-specific interventions to augment their levels of hope.

Our findings significantly supported the mediating role of coping strategies between anxiety and depression, aligning with the research by Mubeen et al. [83]. Coping style, defined as individual strategies to manage, regulate, and alleviate stressful events, is intricately linked to social well-being, as well as mental and physical health. The study observed that adolescents with depression more frequently resort to negative coping mechanisms. These adolescents often exhibit social maladjustment, seeking pleasure in activities like gaming and watching short videos, or engaging in detrimental behaviors like self-harm, smoking, and drinking [84]. Coping style is the actions that potentially worsen depressive symptoms. Earlier research indicates that a negative coping style is a risk factor for anxiety and depression in adolescents during the COVID-19 pandemic [84], predicts psychological symptoms in medical students [60], and correlates with significant academic stress and suicidal ideation in college students [85]. Consequently, cultivating a positive coping style offers significant academic and psychological advantages for adolescents. Overall, this study extended prior research by substantiating the mediating function of coping strategies between anxiety and depression, underscoring the need for medical professionals to be attentive to the coping mechanisms of adolescents with depression and to actively steer them away from negative emotional patterns.

As previously noted, the mediating impact of hope level surpassed that of coping strategies. A plausible explanation for this is the onset of depression typically occurring in early adolescence, with the majority of affected individuals being middle and high school students. During this phase, as adolescents embark on new life stages, their aspirations for academic success, focus on cultivating positive interpersonal relationships, and future planning can all contribute to heightened levels of hope, aligning with findings from Fraser et al. [86]. Additionally, in China, the deep-seated belief that "a good scholar will make an official" underscores the immense significance of academic achievements in shaping adolescents" futures. Consequently, students face a substantial academic burden. An excessive academic load can lead to severe psychological issues, impeding the adoption of positive coping mechanisms. In conclusion, schools should implement effective policies and strategies to bolster teenagers' hope levels, aiding them in navigating the opportunities and challenges of growth, fulfilling heightened academic and social expectations, and facilitating a smooth transition into adulthood.

Through qualitative research, we delineated three major themes and nine sub-themes, thoroughly examining the factors influencing depression in adolescents with depression. In light of recent advancements in positive psychology, this study hypothesized that hope levels and coping styles might impact adolescent depression, considering school, family, and other contextual factors. The findings from our quantitative analysis validated this hypothesis, thereby enriching the application of positive psychology in adolescent depression and offering new perspectives for prevention and intervention within this demographic.

Current psychotherapy for adolescent depression mostly starts from mindfulness intervention, cognitive behavioral therapy, interpersonal psychotherapy, exercise, and diet. This study used a mixed research method to use emerging family- and school-based interventions from positive psychology. A new treatment method for adolescents with depression was explored from a scientific perspective.

This study made up for the shortcomings of this research in the field of positive psychology. It analyzed the depressive factors of adolescents with depression through mixed research methods, and built a mediation model on this basis, integrating family, school and other factors. The coping style and hope level in positive psychology provided a new perspective for the prevention and treatment of adolescent depression, which had important practical significance.

Based on the findings of this study, guidance on family education can be provided from the perspective of family factors, helping parents understand how to create a good family atmosphere and parent-child relationship, as well as how to view the comprehensive development of adolescents correctly. Efforts should be made to increase the publicity of family education and raise social awareness of the importance of family education. From the perspective of schools, communication training for teachers and students should be carried out to improve their communication skills and affinity, encourage schools to carry out diverse teaching activities, meet the learning needs of different individuals, enjoy learning and growth, and create a harmonious learning and living environment for students. Encourage schools and educational institutions to carry out and attach importance to psychological counseling and hope

education courses, and improve individual coping abilities and hope levels.

5. Strengths and limitations

This study, like any other, encompasses both strengths and limitations. Notably, our research adopted a mixed-method approach, analyzing risk factors in adolescent depression and examining the mediating roles of hope level and coping modes. The integration of these diverse analytical methods stands as a clear strength of this study. Through qualitative and quantitative research, we conducted a multi-faceted and in-depth analysis of the depressive factors of adolescents with depression, providing new directions for future family and school intervention, and analyzing from the perspective of positive psychology, enriching positive psychology. Application and development in adolescent depression. Nevertheless, the study also faces certain limitations. Primarily, the research sample was drawn from Henan province in China, thus bearing a regional characteristic. This necessitates extending future research to encompass individuals from other regions and diverse cultural backgrounds for broader applicability. Moreover, the qualitative component of the study involved a single interview session. Conducting multiple interviews in future studies could enhance the accuracy of the findings. Lastly, the study relied solely on adolescents' self-reports. Future research could benefit from incorporating parental reports and evaluations for a more comprehensive understanding.

6. Conclusion

This study enriched the existing theoretical literature on risk factors for adolescent depression, and, building upon this, developed an intermediary model that broadened our comprehension of the interplay between anxiety and depressive symptoms in adolescents with depression. Within this framework, hope levels and coping strategies were identified as mediating factors in the relationship between anxiety and depressive symptoms among these adolescents, with the mediating influence of hope levels being more pronounced than that of coping strategies. Finally, the study underscored the importance of schools and families promptly addressing adolescents' mental health and providing ample emotional support during their developmental years, thereby enhancing their levels of hope and encouraging the adoption of positive coping mechanisms to address their challenges effectively.

Abbreviations

Adolescent depression An affective disorder manifested by either a dysphoric mood or loss of interest or pleasure in usual activities. The mood disturbance is prominent and relatively persistent.

Anxiety Feelings or emotions of dread, apprehension, and impending disaster but not disabling as with ANXIETY DISORDERS.

Hope Belief in a positive outcome.

Coping modes Various techniques for actively managing a stressful event or situation.

Ethical approval statement

As the study's subjects were minors, informed consent was obtained from both the subjects and their guardians prior to commencing the study. The study received approval from the Ethics Committee of Xinxiang Medical College (XYLL—20220003).

Informed consent

Informed consent was obtained from all participants before the data was collected. We informed each participant of their rights and to safeguard their personal information.

Data availability statement

All data generated or analyzed during this study are included in this published article.

Additional information

The case studies and interview data of the 18 interviewees will be made available as supplementary material to support our findings.

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Consent for publication

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CRediT authorship contribution statement

Yan Lin: Supervision, Resources, Project administration. **Zhihan Chen:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Data curation, Conceptualization. **Mengjiao He:** Writing – review & editing, Writing – original draft, Visualization, Data curation. **Weiqing Zhou:** Investigation, Conceptualization. **Lina Wang:** Supervision, Project administration. **Hua Guo:** Project administration, Supervision, Writing – review & editing. **Kaizong Huang:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e35466.

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