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ORIGINAL RESEARCH

Mediating Effects of Sleep Problems and Emotional Symptoms in the Relationship Between Chronotype and Self-Harm Among Adolescents Aged 11–19 Years

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Purpose: Self-harm is linked to numerous adverse health and social outcomes, including repetitive self-harm and an increased risk of suicide. This study aims to explore the influence of chronotype on self-harm among adolescents and further investigate the mediating role of sleep problems and emotional symptoms.

Participants and Methods: The study was conducted between April and June 2022, involving 13 junior and senior high schools in Tianjin. The participants were asked to complete online questionnaires assessing chronotype, sleep problems, depression, anxiety, and self-harm. The data were analyzed and processed using Spearman correlation and mediation effect analysis. Two mediation pathways were tested: Model 1 with sleep problems and depression as the mediators, and Model 2 with sleep problems and anxiety as the mediators.

Results: Participants comprised 13,374 Chinese middle school adolescents (6745 boys) aged 11–19 years. In Model 1, the independent mediation effects of sleep problems and depression were −0.216 (95% CI = [−0.263, −0.172]) and −0.101 (95% CI = [−0.121, −0.083]), accounting for 33.33% and 15.59% of the total effect, respectively. The chain mediation effect was −0.170 (95% CI = [−0.196, −0.146]), accounting for 26.23% of the total effect. In Model 2, the independent mediation effects of sleep problems and anxiety were −0.232 (95% CI = [−0.279, −0.189]) and −0.075 (95% CI = [−0.091, −0.059]), respectively accounting for 35.63% and 11.52% of the total effect. The chain mediation effect was −0.151 (95% CI = [−0.176, −0.128]), accounting for 23.20% of the total effect.

Conclusion: Chronotype is a significant predictor of self-harm, with a later chronotype associated with a higher risk. Both sleep problems and emotional symptoms independently and serially mediate the relationship between chronotype and self-harm. These findings highlight the complex pathways through which chronotype influences self-harm behavior and suggest potential targets for intervention.

Keywords: self-harm, chronotype, sleep problems, emotional symptoms, adolescents

Introduction

Self-harm refers to deliberate actions of self-poisoning or self-injury, regardless of the intended outcome, and is often a response to psychological strain, emotional distress, or mental health challenges.[1] This behavior may act as a coping strategy for some individuals, functioning as a means to manage emotions, self-punish, or signal a need for help.[2] According to the World Health Organization defines adolescence as the age range between 10 and 19 years.[3] In adolescents, self-harm is linked to emotional issues such as depression and anxiety, as well as social, familial, and

environmental factors. Risk factors include adverse childhood experiences, bullying, poor parent-child relationships, and family dysfunction.[2],[4] Moreover, a study conducted among Chinese adolescents identified excessive internet or mobile phone use as a significant risk factor for self-harm.[5] Self-harm typically begins around age13,[6] with about 16% of adolescents reporting having self-harmed at least once,[7] and 8% to 13% engaging in self-harm within the past year.[6] Additionally, 6% to 8% have self-harmed in the past six months.[8] Self-harm is associated with numerous adverse health and social consequences, including a heightened risk of repetitive self-injury and suicide.[9] Self-harm is an important precursor of suicide in children and adolescents. A longitudinal study reveals that the risk of suicide following self-harm is 30 to 130 times higher than that in the general population.[10] Identifying risk factors and promoting prevention is critical for guiding research and interventions.

Chronotype and Self-Harm

Chronotype refers to the individual preference for sleep and wakefulness within the 24-hour circadian rhythm.[11] Three main chronotype are commonly distinguished by researchers: morning type (M-type), neutral type (N-type), and evening type (E-type). M-type prefers early rising and are more productive in the morning, E-type favors later wake-up times and perform better in the evening, while N-type shows no strong preference for early or late activities.[12] Chronotype is flexible and can be influenced by factors like anxiety and depression or modified through interventions such as behavioral therapy and psychoeducation.[13],[14] During adolescence, many individuals shift toward an evening chronotype due to significant changes in sleep patterns. One of the most notable characteristics is the tendency for later sleep timing and the phenomenon often referred to as being a "night owl".[15] About 40% of adolescents report an evening circadian preference during puberty, influenced by social changes like reduced parental control and increased use of technology.[16] In China, academic pressures, including exam preparation, homework, and extracurricular training, push adolescents to study late at night, further shortening sleep duration and exacerbating sleep problems.[17] Therefore, considering the developmental changes driving a delay and lengthening of the circadian rhythm in adolescents and the immense academic pressure they face, it is crucial to investigate the potential harm that a later chronotype may pose to adolescents. Individuals with evening type are more prone to circadian rhythm disruptions, leading to adverse effects such as impaired cognitive function, emotional issues, and a higher likelihood of engaging in risky behavior.[18] While research has examined the negative effects of E-type on mental health and mood, less attention has been given to its impact on self-harm. One study found a close correlation between chronotype and self-harm rates in bipolar patients, with the evening chronotype group demonstrating a significantly higher proportion of self-harm compared to other groups.[19] Another study on adolescents also suggested chronotype affects self-harm.[20] In order to deepen our comprehensive understanding of the link between chronotype and self-harm in adolescents, it's crucial to explore the underlying mechanisms. This enhanced understanding will not only enrich our knowledge of self-harm but also lay the groundwork for more informed prevention, targeted interventions, and robust public health policies.

Mediating Role of Sleep Problems and Emotional Symptoms

Sleep problems encompass a range of dysregulation indicators, including heightened sensitivity to nightmares, difficulty initiating and maintaining sleep, nocturnal awakenings, and daytime dysfunction resulting from poor sleep quality.[21] Multiple factors contribute to these issues, including excessive screen use, physical inactivity, stress, and inconsistent sleep routines.[22–25] Research shows that evening-type individuals tend to have shorter sleep duration, poorer sleep quality, and increased daytime sleepiness compared to morning-type individuals.[26] Moreover, research based on actigraphy-estimated sleep patterns also found that E-type have poorer sleep quality than M-type.[27]

Sleep problems play a crucial role in emotional symptoms, which are also influenced by family environment, social relationships, and physical health.[28–30] Poor sleep quality has been linked to depression and anxiety, with studies showing that evening-type individuals often experience insomnia and require extended sleep compensation on weekends.[31] A study conducted on college students found that the correlation between chronotype and depressive symptoms was mediated by sleep quality. E-type college students with poorer sleep quality were more likely to report higher levels of depressive symptoms.[32] Furthermore, inadequate sleep quality during adolescence has been linked to the onset of anxiety disorders. Longitudinal data link adolescent insomnia to subsequent depression and anxiety onset,[33] while meta-analyses

confirm that poor sleep exacerbates negative emotional states (eg, anxiety, suicidality).[34] These findings indicate a complex pathological correlation between sleep and emotional symptoms among adolescents.

When individuals experience inner pain or emotional turmoil, these emotions may trigger self-harm as a maladaptive coping mechanism to escape the distress caused by negative feelings.[35] Therefore, depression and anxiety are established risk factors for self-harm,[36] particularly when acute emotional distress overwhelms coping capacity.[37] Sleep disruptions may exacerbate this cycle by impairing emotional regulation and reinforcing ineffective coping strategies.[38] A systematic review posits that sleep problems were associated with self-harm, and suggested that cognitive-emotional issues such as emotional dysregulation and depression might mediate the relationship between sleep problems and self-harm.[39]

Current Study

The current study investigates sleep problems and emotional symptoms serially mediate the relationship between chronotype and self-harm among Chinese adolescents. Based on the studies and theories mentioned above, the following hypotheses are proposed:

Hypothesis 1: Chronotype could negatively predict self-harm.

Hypothesis 2: Sleep problems could independently mediate the relationship between chronotype and self-harm.

Hypothesis 3: Emotional symptoms could independently mediate the relationship between chronotype and self-harm.

Hypothesis 4: Sleep problems and emotional symptoms could play a chain-mediating role between chronotype and self-harm.

Materials and Methods
Participants

The study population was derived from the Tianjin Mental Health Promotion Program for Children and Adolescents in Tianjin, China, aimed at investigating the mental health status of middle school students. The study was conducted between April and June 2022, involving 13 junior and senior middle schools in Tianjin. Convenience cluster sampling was employed for an online questionnaire survey. The questionnaires were collected through the Wenjuanxing plat-form (https://www.wjx.cn/app/survey.aspx). Before conducting the survey, uniform training was provided to all personnel involved in the survey to ensure the standardization of the survey process. The training covered the purpose of the survey, guidelines, ethical standards, and operational procedures. During the survey, trained teachers explained the purpose of the study, confidentiality principles, and important considerations to both parents and students. Students willing to participate were required to sign informed consent forms along with their guardians. During the process of completing the survey, students could consult trained teachers online for clarification or to address any questions they had.

Inclusion criteria were as follows: (1) Primary school students in Tianjin; (2) Ability to read and understand the content of the questionnaire correctly; (3) Both students and their parents have provided explicit informed consent and voluntarily participate in the study. Exclusion criteria were as follows: (1) Presence of reading difficulties, leading to the inability to complete the questionnaire or cooperate with the survey; (2) Diagnosed with severe mental illness or organic disease. Ultimately, a total of 13,374 school adolescents aged 11 to 19 were recruited to participate in the study and were asked to complete a survey questionnaire. Informed consent was obtained from all participants and their parents, and the study was approved by the ethics committee of Tianjin Anding Hospital (No.2021–42). The procedures used in this study adhere to the 1964 helsinki Declaration and its subsequent amendments, as well as the pertinent ethical regulations of the national and internal research committees.

Measures

Chronotype

The morning and evening questionnaire (MEQ) is a widely used tool for assessing the natural trend of sleep–wake circadian rhythm.[40] MEQ-5,[41] a simplified version of the MEQ, was employed to measure the chronotype. The Chinese version of the MEQ-5 has been proven to have good reliability and validity in Chinese middle school students, with Cronbach's alpha coefficient of 0.74.[42] In this study, the Cronbach's α of the MEQ-5 was 0.76. Scores on the MEQ-5 range from 4 to 25, with higher scores reflecting higher morningness preference and lower scores indicating eveningness preference.

Sleep Problems

The Pittsburgh Sleep Quality Index was used to measure the overall quality of sleep.[43] The PSQI was initially translated into Chinese by Liu et al and was subjected to reliability and validity testing in the Chinese population. The results showed that the Chinese version of the PSQI demonstrated good reliability and validity, with a Cronbach's alpha coefficient of 0.89.[44] The Chinese version of the PSQI has been widely used in various studies and has demonstrated good reliability and validity.[45,46] The PSQI contains 18 items to assess 7 domains including subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. All answers are scored from 0 to 3. The total score ranges from 0 to 21, with higher scores indicating higher levels of sleep problems. In our study, the Cronbach's alpha coefficient of the PSQI was 0.72.

Emotional Symptoms

The Mental Health Inventory of Middle-school students (MMHI-60) is a scale developed by Chinese psychologist. In the current study, depression subscale and anxiety subscale from the MMHI-60 were used to evaluate emotional symptoms.[47] The depression subscale consists of 6 items, each scored on a five-point scale. The final score on depression is the average of six items, according to which the depression severity was divided in to four levels: < 2 no depression; 2 to 2.99, mild; 3 to 3.99, moderate; and ≥ 4, severe. The anxiety subscale also consists of 6 items, and the final anxiety score is the average of these six items. Based on the anxiety score, anxiety severity was divided into four levels: < 2 no anxiety; 2 to 2.99 mild anxiety; 3 to 3.99 moderate anxiety; and ≥4 severe anxiety. MMHI-60 has been proven to have good reliability and validity and has been widely used in China to measure the mental health of middle school students.[48] In this study, the Cronbach's alpha coefficients for the Depression subscale and Anxiety subscale were 0.91 and 0.93, respectively.

Self-Harm

Self-harm was assessed by asking the following question: "Did you engage in self-harming behaviors in the past six months?" Responding "yes" was coded as 1, while responding "no" was coded as 2. If answered "yes", participants were asked to specify the specific behaviors and frequency of self-harm within the last six months. Additionally, they were asked to rate the severity of the self-harm behavior on a scale of 1 to 4, ranging from mild to severe.

Statistical Analyses

SPSS Windows software version 27.0 was used to conduct the data analyses. Categorical data were reported as counts and percentages. Normally distributed variables were reported as mean and standard deviation (SD), and differences in means were compared using t-tests. Non-normally distributed continuous variables were reported as median and Interquartile range (IQR), and differences in medians were compared using the Mann–Whitney U-test. Spearman correlation analysis was used to examine the correlations among the variables (chronotype, sleep problems, depression, anxiety, and self-harm). The PROCESS macro uses a path analysis modeling tool based on regression to assess variables' direct and indirect effects.[49] To improve the performance and stability of the model, all continuous variables were standardized using Z-score normalization before fitting the chained mediation model.[50] In this study, we performed chained mediation analyses using Model 6 with 5000 bias-corrected bootstrap samples.

Results

Descriptive Statistics

As shown in Table 1, among 13,374 participants, the average age was 15.21 ± 1.4 years, with 50.4% (n=6745) being boys. A majority were non-only children (70.0% [n=9366]), from families with a general economic status (75.6% [n=10113]), and with parents in a normal marital relationship (87.8% [n=11737]). Self-harm was reported by 413 (3.1%) students over the past six months. Significant differences were observed in all demographic variables, including student's age, gender, only child status, family economic status and parental marital status, between adolescents with self-harm and those without self-harm.

As indicated in Table 2, the Chronotype scores of participants without self-harm (median: 15.0 [IQR: 13.0, 17.0]) were higher than those with self-harm (median: 12.0 [IQR: 10.0, 15.0]) ($p < 0.01$). This suggests that adolescents in the self-harm group tend to prefer eveningness. The sleep problem scores of the self-harm group (median: 9.0 [IQR: 6.0, 11.0]) were higher than those of the non-self-harm group (median: 4.0 [IQR: 2.0, 6.0]) ($p < 0.01$). This indicates that the self-harm group has more severe sleep problems. In terms of depression, the self-harm group (median: 3.7 [IQR: 2.8, 4.5]) ($p < 0.01$) scored higher than the non-self-harm group (median: 1.7 [IQR: 1.2, 2.5]). Similarly, for anxiety, the self-harm group (median: 3.7 [IQR: 2.7, 4.7]) ($p < 0.01$) scored higher than the non-self-harm group (median: 1.7 [IQR: 1.2, 2.5]). The median depression and anxiety scores of the non-self-harm group were both 1.7, indicating no depression or anxiety. The self-harm group had median scores

Table 1 Characteristics of the Participants (n=13374)

Characteristics	Total n=13374	No Self-harm N=12961(96.9)	Self-harm n=413(3.1)	t-test/ Chi-square
Student's Age, Mean (SD)	15.21(1.4)	15.22(1.4)	14.97(1.4)	3.38***
Student's Gender, N (%)				56.66***
Boy	6745 (50.4)	6612 (51.0)	133 (32.2)	
Girl	6629 (49.6)	6349 (49.0)	280 (67.8)	
Only child status, N (%)				5.64*
Yes	4008 (30.0)	3906 (30.1)	102 (24.7)	
No	9366 (70.0)	9055 (69.9)	311 (75.3)	
Family Economic status, N (%)				128.06***
Very difficult	240 (1.8)	218 (1.7)	22 (5.3)	
Relatively difficult	1917(14.3)	1791 (13.8)	126 (30.5)	
General	10113 (75.6)	9877 (76.2)	236 (57.1)	
Relatively rich	1020 (7.6)	992 (7.7)	28 (6.8)	
Very rich	84 (0.6)	83 (0.6)	1(0.2)	
Parental Marital status, N (%)				66.12***
Married	11737 (87.8)	11,422 (88.1)	315 (76.3)	
Remarried	704 (5.3)	649 (5.0)	55 (13.3)	
Lone parent	933 (7.0)	890 (6.9)	43 (10.4)	

Notes: *p < 0.05, ***p < 0.001.
Abbreviation: SD, standard deviation.

Table 2 Characteristics of Main Study Variables

Characteristics	Total Median (IQR)	No Self-harm Median (IQR)	Self-harm Median (IQR)	P Value[a]
Chronotype	15.0(13.0, 17.0)	15.0(13.0, 17.0)	12.0(10.0, 15.0)	< 0.001
Sleep problems	4.0 (2.0, 6.0)	4.0 (2.0, 6.0)	9.0 (6.0, 11.0)	< 0.001
Depression	1.8 (1.2, 2.5)	1.7 (1.2, 2.5)	3.7 (2.8, 4.5)	< 0.001
Anxiety	1.7 (1.2, 2.7)	1.7 (1.2, 2.5)	3.7 (2.7, 4.7)	< 0.001

Notes: IQR, interquartile range (75th quartile minus 25th quartile); [a]P value was based on Mann–Whitney U-test.

between 3 and 4, suggesting moderate anxiety. The self-harm group's depression and anxiety scores were significantly higher than those of the non-self-harm group. This suggests that self-harm is closely related to higher levels of emotional symptoms.

Correlation Analysis

The results of Pearson correlation analysis are presented in Table 3. Chronotype was negatively correlated with sleep problems, depression, anxiety and self-harm (r = −0.401, p < 0.01; r = −0.343, p < 0.01; r = −0.332, p < 0.01; r = −0.123, p < 0.01, respectively). Sleep problems showed a positive correlation with depression, anxiety and self-harm (r = 0.594, p < 0.01; r = 0.603, p < 0.01; r = 0.192, p < 0.01, respectively). Furthermore, depression and anxiety were positively correlated with self-harm (r = 0.217, p < 0.01; r = 0.206, p < 0.01, respectively).

Chain Mediation Results

The results of the mediation analysis for chronotype, sleep problems, emotional symptoms, and self-harm are presented in Tables 4 and 5.

Table 3 Correlations for the Main Study Variables (N = 13,374)

Variable	1	2	3	4	5
1. chronotype	1	−0.401***	−0.343***	−0.332***	−0.123***
2. Sleep problems	–	1	0.594***	0.603***	0.192***
3. Depression	–	–	1	0.901***	0.217***
4. Anxiety	–	–	–	1	0.206***
5. Self-harm	–	–	–	–	1

Note: ***p < 0.001.

Table 4 Chain Mediation Model Between Chronotype and Self-Harm (Depression)

Path	Effect Size	Boot SE	LLCI	ULCI	Percentage of Total Effect
Chronotype (X) → Sleep problems (M1) →Depression(M2) → Self-harm (Y)					
Direct effect	−0.161	0.058	−0.275	−0.046	24.85%
Total indirect effect	−0.487	0.024	−0.537	−0.443	75.15%
X → M1→Y	−0.216	0.023	−0.263	−0.172	33.33%
X → M2→Y	−0.101	0.010	−0.121	−0.083	15.59%
X → M1→ M2→Y	−0.170	0.012	−0.196	−0.146	26.23%

Notes: Bootstrap sample size =5000. Covariates: Age; Gender; Only child status; Family Economic Situation; Marital status.
**Abbreviations**: LL, low limit; CI, confidence interval; UL, upper limit.

Table 5 Chain Mediation Model Between Chronotype and Self-Harm (Anxiety)

Path	Effect size	Boot SE	LLCI	ULCI	Percentage of Total Effect
Chronotype (X) → Sleep problems (M1) →Anxiety(M2) → Self-harm (Y)					
Direct effect	−0.193	0.058	−0.307	−0.079	29.65%
Total indirect effect	−0.458	0.023	−0.506	−0.414	70.35%
X → M1→Y	−0.232	0.023	−0.279	−0.189	35.63%
X → M2→Y	−0.075	0.008	−0.091	−0.059	11.52%
X → M1→ M2→Y	−0.151	0.012	−0.176	−0.128	23.20%

Notes: Bootstrap sample size =5000. Covariates: Age; Gender; Only child status; Family Economic Situation; Marital status.
Abbreviations: LL, low limit; CI, confidence interval; UL, upper limit.
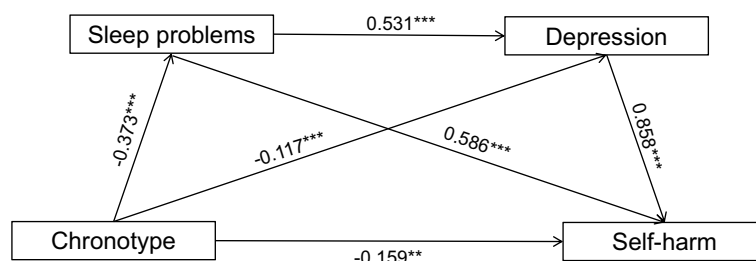
Figure 1 Chain mediation model (Depression).
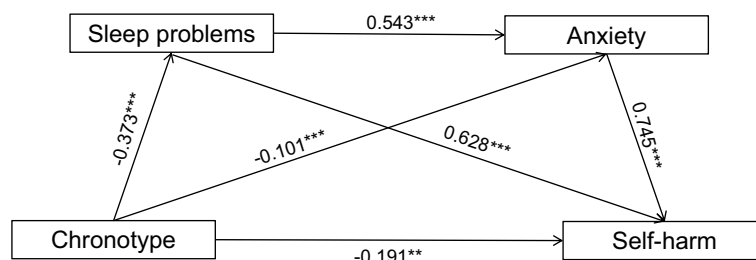**Notes**: **p < 0.01, ***p < 0.001.

Figure 2 Chain mediation model (Anxiety).
Notes: **p < 0.01, ***p < 0.001.

For depression, as shown in Figure 1, the path coefficients indicate that all relationships in the model are significantly positive or negative. The mediation model comprised three indirect effects: the mediating effect value of Path 1 (chronotype → sleep problems → self-harm) was −0.216 (95% CI = [−0.263, −0.172]), accounting for 33.33% of the total effect; Path 2 (chronotype → depression → self-harm) was −0.101(95% CI = [−0.121, −0.083]), accounting for 15.59% of the total effect; and Path 3 (chronotype → sleep problems → depression → self-harm) was −0.170 (95% CI = [−0.196, −0.146]), accounting for 26.23% of the total effect. The 95% confidence intervals for these three paths did not include 0, indicating that all three indirect effects were statistically significant.

For Anxiety, as shown in Figure 2, the path coefficients indicate that all relationships in the model are significantly positive or negative. The mediating effect value of Path 1 (chronotype → sleep problems → self-harm) was −0.232 (95% CI = [−0.279, −0.189]), accounting for 35.63% of the total effect; Path 2 (chronotype → Anxiety → self-harm) was −0.075 (95% CI = [−0.091, −0.059]), accounting for 11.52% of the total effect; and Path 3 (chronotype → sleep problems → Anxiety → self-harm) was −0.151(95% CI = [−0.176, −0.128]), accounting for 23.20% of the total effect. The 95% confidence intervals for these three paths did not include 0, indicating that all three indirect effects were statistically significant.

Discussion

This study used a cross-sectional design to examined in greater detail the potential mechanisms linking chronotype and self-harm in adolescents. The survey results showed that the self-harm rate among the adolescents in the sample was 3.1% within six months, and chronotype was a direct predictor of self-harm. Consistent with the hypothesis, the results revealed that sleep problems and emotional symptoms can independently mediate the association between chronotype and self-harm. Moreover, sleep problems and emotional symptoms also exhibit significant chain of tragedy effect in the relationship between chronotype and self-harm. This research enhances the understanding of the underlying mechanisms of self-harm among Chinese adolescents.

In our large sample of Chinese adolescents aged 11–19, 3.1% reported engaging in self-harm in the past 6 months. This rate is close to the reported self-harm rate of 5.3% in a large sample study conducted in Shanxi Province, China,[51] but much lower than the 24.3% reported by another study.[52] The prevalence rates of self-harm appear to vary widely across various studies. Muehlenkamp et al pointed out potential reasons.[53] Firstly, the assessment format used appears to

significantly influence estimates of self-harm rates showing lower rates when using a single-item format assessment. For instance, individuals assessed using single item assessments (dichotomous Yes/No response) reported an average lifetime prevalence of 12.2%, whereas those assessed using multiple-item or behavior checklists reported an average prevalence of 31.4%. Our study employed a single-item assessment, hence resulting in lower prevalence rates. Secondly, the prevalence of self-harm varies depending on the assessment time frame. The average prevalence rate of self-harm assessed over a period of 12 months is often twice as high as that assessed over a period of 6 months.

Our study identified significant demographic disparities in self-harm prevalence. Females represented 67.8% of self-harm cases versus 32.2% of males, aligning with evidence that females exhibit heightened vulnerability due to increased psychological distress, rumination, and maladaptive coping strategies.[20,54] Non-only-children, particularly females, also demonstrated elevated self-harm risk, potentially linked to familial resource scarcity and reduced parental attention amplifying psychological stress.[55] The chi-square analysis revealed that adolescents with poor family economic status had a higher proportion of self-harm. The finding consistent with many previous studies.[56,57] This may be because adolescents facing household financial difficulties experience higher stress levels compared to those without such challenges.[58] The proportion of adolescents engaging in self-harm is higher among those from single-parent or remarried families. This may be due to the fact that adolescents from broken families often face additional challenges, such as emotional distress, social isolation, and difficulty in forming healthy relationships.[59–61]

Previous research exploring the association between chronotype and self-harm has been extremely limited. This study constructed a multiple mediation model to investigate the relationship between chronotype and self-harm, as well as its mechanisms. We analyzed two chain mediation models. In the model with sleep problems and depression as mediators, the direct effect of chronotype on self-harm accounted for 24.85% of the total effect, while the chain mediation effect accounted for 26.23%. In the model with sleep problems and anxiety as mediators, the direct effect of chronotype on self-harm accounted for 29.65% of the total effect, whereas the chain mediation effect accounted for 23.20%. These findings suggest that a later chronotype is associated with a higher risk of self-harm. The current results were in line with previous studies in clinical patients or general adolescents. A previous study conducted with 205 patients with bipolar disorder found that self-harm group had significantly lower MEQ scores than that in no self-harm group, indicating that evening chronotype is a risk factor for self-harm in BD patients.[19] Another study also found that students with a later chronotype are more likely to engage in self-harm, which is consistent with this study.[20] What sets our study apart from previous research is that we further investigated the mechanisms underlying the association between chronotype and self-harm. Our findings reveal that the association between chronotype and self-harm can be mediated by sleep problems and emotional symptoms, further extending previous research findings. Specifically, a later chronotype may contribute to more sleep problems, which intensify emotional symptoms and further increase the risk of self-harm among adolescents. Sleep is often closely linked to emotions. Sleep patterns and emotional processing in neurophysiology and neuropathology controlled by complex mechanisms. Wirz-Justice et al have pointed out that sleep affect mood through neurotransmitter switching, stress modulation, clock genes, neuroplasticity, and neuroinflammation.[62] Lefter et al found that an interaction between sleep processes and emotional states relies on the activity of several key brain structures, such as the amygdala and hippocampus.[63] A neurobiological study conducted among adolescents found that during emotional activation tasks, stronger amygdala and hippocampal responses were observed in adolescents with self-harm compared to the control groups.[64] Therefore, evidence based on physiological mechanisms also seems to suggest the association between sleep, emotions, and self-harm, which is consistent with our research findings. Later chronotype and poorer sleep problems may lead to mood swings, anxiety, and depression.[65] These emotional symptoms are critical factors that directly contribute to adolescents' engagement in self-harm. In conclusion, delayed chronotype may lead to disruptions in circadian rhythms, consequently affecting sleep problems and emotional states. Adolescents with evening chronotypes may experience sleep problems and are more prone to negative emotions, which may prompt them to seek unhealthy coping mechanisms such as self-harm. Our research findings support this viewpoint.

Our research findings highlight the association between a later chronotype and self-harm and underscore the mediation effect of sleep problems and emotional symptoms. The results have significant implications for the prevention and intervention of self-harm behaviors in future studies. Despite the strengths of the current study, such as its large sample size and examination of both direct and indirect associations, there are several limitations to

consider. Firstly, cross-sectional methods cannot infer causality between variables. Longitudinal follow-up designs and intervention experiments could be employed in future research to better verify the influence of chronotype on self-harm and the mediating roles of sleep problems and emotional symptoms. Secondly, a convenience sampling method was utilized, and only schools from the Tianjin region of China were selected, which may limit the generalizability of our results. Lastly, in this study, chronotype and sleep problems were measured using self-report measures. Although the reliability and validity of these measurement tools have been demonstrated, biases are inevitable Future research could employ self-report combined with actigraphy technology to more finely and scientifically measure chronotype and sleep problems.

Despite these limitations, the current analyses contribute to a better understanding of adolescent self-harm behavior and provide us with more ideas on how to prevent adolescent self-harm. Based on the results, we recommend implementing targeted interventions. Existing research has demonstrated the effectiveness of certain approaches in reducing eveningness preference among adolescents. One such approach is the Transdiagnostic Sleep and Circadian Intervention, a structured, evidence-based psychological treatment.[16] Another effective method is psychoeducation, which primarily encourages participants to engage in activities like yoga, meditation, and outdoor appreciation.[66] In addition to these approaches, proactive measures such as psychotherapy, pharmacological treatment, and physical exercise should be employed to address sleep disturbances and regulate emotional distress.[67] These efforts are essential to prevent further deterioration that could increase the risk of self-harm among adolescents.

Conclusion

Chronotype negatively predicts self-harm, with a later chronotype associated with a higher risk of self-harm. Both sleep problems and emotional symptoms independently and serially mediate the link between chronotype and self-harm. This cascade mechanism suggests that delayed circadian preferences exacerbate sleep deficits, which subsequently amplify emotional vulnerability and maladaptive coping behaviors. These results underscore the importance of addressing chronobiological factors and implementing sleep-focused interventions to disrupt this pathological progression in adolescent mental health.

Data Sharing Statement

The datasets that support the findings of this study are available upon reasonable request to the corresponding authors.

Ethical Committee Permission

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the ethics committee of Tianjin Anding Hospital (No.2021-42).

Informed Consent

Informed consent was obtained from all participants and their parents/guardians.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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