Reciprocal Effect between Depressive Symptoms and Adolescent Non-suicidal self-injury before and after COVID-19: A Longitudinal Study

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Abstract

Background

Non-suicidal self-injury (NSSI) is a common psychological and behavioral problem among adolescents and has now become a major public health problem for adolescents. Since the COVID-19 outbreak in 2019, it has caused various mental health problems, such as anxiety, depression, and mental burnout, contributing to a severe mental health crisis globally. Thus far, a few studies recorded the temporal change in adolescents’ psychological status during the COVID-19 pandemic as well as that with the implementation of large-scale public health intervention methods, and this study adds to the evidence.

Methods

Based on the Chengdu Positive Child Development (CPCD) survey, the baseline dataset was collected in December 2019, and the first follow-up of the CPCD was conducted in July 2020. A total of 6,023 adolescents aged 10-19 were recruited from five primary and middle schools. Two independent autoregressive cross-lagged models were used to test the bidirectional relationship between NSSI and depressive symptoms in adolescents; logistic regression analysis was used to explore the predictors of NSSI implementation in adolescents with depressive symptoms, which could provide an entry point for behavioral interventions to NSSI.

Results

The prevalence of depressive symptoms among our participants was 32.69% at baseline, and 34.27% at follow-up. The occurrence rate of NSSI in adolescents who may have depressive symptoms was 44.34%, and that during the pandemic was 53.44%. The difference was statistically significant ($P < 0.05$). The results of the binary logistic analysis showed that among adolescents, gender, duration of the online class, depression mood, place of residence, and self-perception of relationship with caregivers were the risk factors for NSSI (or $\beta > 0$), and daily sleep hours positive mood was the protective factor (or $\beta < 0$). The lag effect of adolescent depression on their NSSI behavior is significant, which means that based on controlling the adolescent baseline NSSI, the deeper the adolescent depression degree, the more frequent their NSSI behavior ($\beta=0.26$, $P<0.01$). At the same time, adolescents’ NSSI behavior also had a lagging effect on depressive symptoms, and adolescents with self-injury behavior were more likely to be depressed ($\beta=0.02$, $P<0.01$). Depression and NSSI are mutual($\beta=0.77$, $P<0.05$ $\beta=0.27$, $P<0.01$).

Conclusions

The increased depressive symptoms among adolescents exacerbated their NSSI behaviors and hurt their mental health during COVID-19. Screening for depression should be carried out early to serve as a warning sign in preventing and reducing NSSI in adolescents.

1. Background

Since the start of the COVID-19 pandemic in December 2019, the lockdown strategy taken to control the transmission of the virus has had a far-reaching impact on people’s daily life around the world. The mental
burden that the pandemic drew on people has caused numerous negative mental health issues, such as anxiety, depression, and mental burnout, contributing to a severe mental health crisis globally. To mitigate the situation, the Chinese government has implemented several strict prevention strategies nationwide such as demanding social distancing in public places, quarantine, and lockdowns. Measures like city lockdowns and suspension of enterprises and schools were taken in Wuhan and Shanghai when numerous cases of COVID-19 were diagnosed. These measures were proven effective in cutting off the transmission of the virus. Nevertheless, due to the uncertainty of COVID-19 infection, worry might occur among everyone, which could lead to a COVID-19-induced mental health crisis. Pandemic and quarantine-induced comprehensive psychological pressure can intensify anxiety and depression among adolescents. In addition, excessive fear of being infected can bring about acute stress and anxiety and is likely to cause subsyndrome-level or syndrome-level depression among fragile individuals. The National Center for Suicide Research and Prevention of Mental Ill-health (NASP) pointed out that risk factors, including prolonged periods of social isolation, economic loss due to unemployment and lockdown, and the death of family members or significant others, can increase the prevalence of self-harm behaviors among adolescents in this pandemic. Salari and his colleagues pointed out that the COVID-19 pandemic did not only raise concerns among people regarding public health but also caused certain psychological and mental disorders. A systematic review of COVID-19-related emotional disturbance reveals that, among ordinary people in China, Denmark, Iran, Italy, Nepal, Spain, America, and Turkey, the prevalence of anxiety (6.3% to 50.9%), depression (14.6% to 48.3%), Post-Traumatic Stress Disorder (7% to 53.8%), emotional disturbance (34.4% to 38%), and stress (8.1% to 81.9%) are all relatively high. Adolescents are at the stage of development and have unique biological, psychological, and social risk factors, which may be affected by the pandemic.

Non-suicidal self-injury (NSSI) refers to the direct intentional destruction of one's own body without suicidal intent, including cutting, scratching, burns, stabbing, biting, etc., yet not life-threatening. Non-suicidal self-injury (NSSI) is a common psychological and behavioral problem among adolescents has and now become a major public health problem for adolescents. Affected by multiple risk factors on the biological, psychological, environmental, cultural, and other sides, adolescents were turned into a high-risk population of NSSI, with a lifetime prevalence of 17.2%. Meanwhile, NSSI is increasingly recognized as a serious problem related to various adverse psychological symptoms. From 2008 to 2018, the global prevalence of depressive symptoms increased by approximately 20% and continues to trend upward. The lasting COVID-19 may aggravate adolescents’ depression. Extended holidays due to the COVID-19 pandemic may bring psychological pressures. Lack of contact among peers and reduced opportunities for stress management may be the main concerns of adolescents during COVID-19. The results of COVID-19 on mental health may vary among different populations. The pandemic and its management measures can bring about stronger responses among vulnerable groups, such as those who previously suffered from mental illness. Adolescents with mental health problems may suffer from more severe emotional distress and behavioral problems. To cope with the stress related to COVID-19, adolescents may commit NSSI as an emotional outburst. A systematic evaluation of 39 studies pointed out that, based on adolescents’ depressive symptoms, one can predict their chances of committing NSSI in the future. A longitudinal study with a sample of 813 Chinese adolescents also showed that higher levels of depressive symptoms were associated with an increase in NSSI one year later. Therefore, this study hypothesized that during COVID-19, psychological health among adolescents deteriorated,
and the prevalence of NSSI among adolescents with depressive symptoms increased compared with that before the pandemic.

Thus far, there is a relatively small record of longitudinal change in adolescents’ psychological status during the COVID-19 pandemic as well as with the implementation of large-scale public health intervention methods\textsuperscript{14-16}. The data about mental health changes among adolescents is rare in general, which could provide an entry point for behavioral interventions to NSSI. At baseline, there have been studies indicating the cross mechanism between NSSI and depressive symptoms. Depression is a risk factor for NSSI, and NSSI can be used to predict the occurrence of depressive symptoms. Cross-sectional studies emphasize the importance of depressive symptoms as a statistical mediator of the horizontal link between adverse experiences and NSSI\textsuperscript{17,18}. However, just a few longitudinal studies have studied the impact of depressive symptoms on adolescents’ NSSI. To investigate the influence of depressive symptoms on NSSI among adolescents and the occurrence rate of NSSI among adolescents with depressive symptoms, we performed this longitudinal study. Furthermore, to assess the bidirectional association between depressive symptoms and NSSI to provide more evidence for the longitudinal study of NSSI in Chinese adolescents.

2. Methods

2.1 Design and Participants

Based on the Chengdu Positive Child Development (CPCD) survey\textsuperscript{19}, using the method of multi-stage random cluster sampling and stratified according to geographical and economic conditions, a total of five elementary schools were selected from urban areas, suburban counties, and rural towns in Chengdu. The data collection is carried out in two rounds (waves). The baseline survey of all middle school students from five schools was conducted from December 23, 2019, to January 13, 2020 (before the pandemic, at baseline), and the first follow-up survey was conducted when schools reopened after the COVID-19 outbreak from June 16 to July 8, 2020 (during the pandemic, at follow-up). There were 6776 questionnaires collected from adolescents aged 10-19 years old as the study population. Excluded the questionnaires with more missing (variable missing more than 20%), not answering carefully, and inconsistent personal information in the two surveys, and finally, include 6023 valid respondents. A total of 6023 participants completed the whole study, and the response rate was 88.89%. The data was gathered via questionnaires that were handed to researchers immediately after the participants finished them individually. A longitudinal study was applied to analyze the changes in NSSI and depressive symptoms among adolescents at baseline and follow-up and to explore the bidirectional relations between NSSI and depressive symptoms.

2.2 Measuring tools

2.2.1 Deliberate Self-Harm Inventory, DSHI

NSSI was measured using Deliberate Self-Harm Inventory (DSHI). Adolescents were asked if they had ever experienced a self-injury in their life course, including cutting, burning, scratching, biting, stabbing, and other eight NSSI types. If the answer was one or more times, they were considered self-injury. The Cronbach's $\alpha$ for the surveyed sample is 0.875.
2.2.2 Center for Epidemiologic Studies Depression Scale for Children, CES-DC

The Center for Epidemiologic Studies for children (CES-DC)\textsuperscript{20} was utilized to assess the depressive symptoms of the participants in the past week. It had been examined the dimensionality and factorial invariance as well\textsuperscript{21}. 20 entries are included in this scale and these entries are divided into 4 dimensions: depressive mood, positive mood, physical symptoms, and interpersonal relationship. With a full score of 60, a total score smaller than 15 indicates no depressive symptoms, a total score ranging from 16 to 27 indicates the likelihood of depressive symptoms, and a total score greater than 27 indicates definite depressive symptoms. Participants with the likelihood of depressive symptoms and definite depressive symptoms were considered to have depressive symptoms\textsuperscript{22}. The Cronbach's $\alpha$ of this study is 0.84.

2.2.3 Demographics and COVID-19 infection history

The demographic information includes nine items: age (year), sex (boy or girl), self-evaluation of relationship with caregivers (do you have a good relationship with your caregivers? "1" means very bad, "10" means very good), place of residence (city and suburb), sleep time, exercise time and duration of online classes during the pandemic, history of COVID-19 infection (have you or your family members been infected by COVID-19?), And unemployment during the epidemic (is your family unemployed due to covid-19?).

2.3 Data Analysis

Data were analyzed using SPSS (version 22.0) and Mplus (version 7.3). Descriptive statistics include mean and standard deviation (SD) for continuous variables, frequency, and percentage for categorical variables. To unravel the relationship between depression and NSSI, t-test, Chi-square, and logistic regression models were used.

Cross-lagged analysis (using Mplus version 7.3) was utilized to explore the bidirectional relationship between depressive symptoms and NSSI. The model was evaluated using two fitting indices that are sensitive to the misdescription of the model: the comparative fit index (CFI) and root mean square error of approximation (RMSEA). The CFI (Comparative fit index, CFI) and TLI (Tucker-Lewis index) values of more than 0.95 are considered acceptable, and RMSEA (Root mean square error of approximation, RMSEA) value of less than 0.08 suggests a reasonable fit, whereas values $<0.05$ suggest good fit. Models with higher CFI, TLI values, and lower RMSEA values generally reflect better model fit. Furthermore, we also investigated the results of the model $\chi^2$ test, $\chi^2$/df (Degree of freedom) value less than 3 fits the data well\textsuperscript{23}.

3. Results

3.1 sample characteristics

6023 adolescents were included in this analysis, the age of the baseline survey was 11.63 (1.54) years, and the age of the second-round survey was 12.05 (1.51) years. 3121 boys (51.82\%) and 2902 girls (48.18\%).
participated in the survey. 5048 adolescents (89.78%) assessed their relationship with caregivers as good (≥ 5 points), and 615 adolescents (10.21%) assessed such relationship as bad (< 5 points). Among all adolescents included, 3679 (61.08%) lived in cities and towns, and the remaining 2344 (38.92%) lived in rural areas. During the pandemic period, the average daily duration of sleep of adolescents was 8.63 (1.72) hours, the average duration of physical exercise was 1.59 (1.62) hours, and the average duration of online classes was 5.64 (2.92) hours. 111 people (1.84%) had a history of COVID-19 infection, and 732 families (12.15%) lost their jobs due to COVID-19.

At baseline, the number of NSSI detected in boys (29.61%) was higher than that in girls (27.65%). at follow-up, the number of NSSI detected in girls (35.73%) was higher than that in boys (33.49%). Among the students with depressive symptoms, the occurrence rate of NSSI was 44.34% and 53.44% respectively in the two rounds (waves) of the survey, and the occurrence rate of NSSI increased, Among the students without depressive symptoms, the occurrence rate of NSSI decreased. The occurrence rate of students who considered having a bad relationship with their caregivers was high, at 31.87% at baseline and 60.55% at follow-up. The occurrence rate of NSSI among students residing in rural areas was increasing, at 33.36% at baseline and 35.41% at follow-up. The occurrence rate of NSSI among adolescents with a COVID-19 infection history was high at 34.23%. The NSSI occurrence rate of students from families unemployed due to covid-19 was 35.52% higher than that of families without unemployment. (Table 1)

Table 1. Occurrence of NSSI in teenagers with different demographic characteristics (N=6023)
<table>
<thead>
<tr>
<th>Demographic characteristics</th>
<th>Number of people</th>
<th>Number of NSSI occurrences</th>
<th>Incidence%</th>
<th>$X^2/t$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W1</td>
<td>W2</td>
<td>W1</td>
<td>W2</td>
<td>W1</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Boy</td>
<td>3121</td>
<td></td>
<td>924(29.61%)</td>
<td></td>
<td>863(27.65%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>568.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Girl</td>
<td>2902</td>
<td></td>
<td>972(33.49%)</td>
<td></td>
<td>1037(35.73%)</td>
</tr>
<tr>
<td>Depressive symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>568.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Yes</td>
<td>1969</td>
<td>2064</td>
<td>1023(44.34%)</td>
<td></td>
<td>1103</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>No</td>
<td>4054</td>
<td>3959</td>
<td>873(21.53%)</td>
<td></td>
<td>797(20.13%)</td>
</tr>
<tr>
<td>Self-perception of relationship with caregivers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥5points</td>
<td>5452</td>
<td>5407</td>
<td>1714(31.44%)</td>
<td></td>
<td>1527(28.04%)</td>
</tr>
<tr>
<td>5points</td>
<td>571</td>
<td>616</td>
<td>182(31.87%)</td>
<td></td>
<td>373(60.55%)</td>
</tr>
<tr>
<td>Place of residence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>City or town</td>
<td>3679</td>
<td>1114</td>
<td>1070(29.08%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural area</td>
<td>2344</td>
<td>782</td>
<td>830(35.41%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COVID-19 infection history</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>/</td>
</tr>
<tr>
<td>Yes</td>
<td>/</td>
<td>111</td>
<td>/</td>
<td></td>
<td>38(34.23%)</td>
</tr>
<tr>
<td>No</td>
<td>/</td>
<td>5912</td>
<td>/</td>
<td></td>
<td>1862(31.50%)</td>
</tr>
<tr>
<td>Unemployed due to COVID-19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>/</td>
</tr>
<tr>
<td>Yes</td>
<td>/</td>
<td>732</td>
<td>/</td>
<td></td>
<td>260(35.52%)</td>
</tr>
<tr>
<td>No</td>
<td>/</td>
<td>5291</td>
<td>/</td>
<td></td>
<td>1640(31.00%)</td>
</tr>
</tbody>
</table>

### 3.2. Changes in non-suicidal self-injury and depressive symptoms in adolescents at baseline and follow-up

To assess the differences between baseline and follow-up, paired t-test of depressive symptoms and NSSI behaviors was conducted. The NSSI frequency increased from 1.25 (3.07) at baseline to 1.40 (3.32) at follow-
up (P < 0.01). The depression score increased from 14.15 (10.34) at baseline to 14.55 (10.90) at follow-up (P < 0.01). Table 1 summarizes the changes in depressive symptoms and NSSI at baseline and follow-up. In the two time points of the study, some differences in the number of adolescents with depressive symptoms committing NSSI at baseline and follow-ups were also noted. (Table 2, Fig. 1)

Table 2. Variations of NSSI and depressive symptoms at baseline and follow-up (N=6023)

<table>
<thead>
<tr>
<th>Grouping</th>
<th>at baseline</th>
<th>at follow-up</th>
<th>Paired T-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean± SD</td>
<td>Mean± SD</td>
<td>Z P</td>
</tr>
<tr>
<td>NSSI</td>
<td>1.25±3.07</td>
<td>1.40±3.32</td>
<td>-3.48 &lt;0.01</td>
</tr>
<tr>
<td>Depressive symptoms</td>
<td>14.15±10.34</td>
<td>14.55±10.90</td>
<td>-3.09 &lt;0.01</td>
</tr>
</tbody>
</table>

a Note: SD=Standard Deviation.

### 3.3 Differences in depressive symptoms among adolescents at baseline and follow-up

Results from McNemar suggest differences in the occurrence rate of depressive symptoms at baseline and follow-up. And the occurrence rate of depressive symptoms among adolescents during the COVID-19 pandemic was higher than that at baseline (P < 0.05) (Table 3). In addition, according to the analysis from the independent sample test, differences exist in the scores of depressive moods, positive moods, physical symptoms, activity retardation, and interpersonal relationship between the depressive group and the non-depressive group (P < 0.001). (Table 4)

Table 3 Changes in the occurrence rate of depression in teenagers at baseline and follow-up

<table>
<thead>
<tr>
<th>W2</th>
<th>W1</th>
<th>X2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of depressive symptoms</td>
<td>1201 19.94%</td>
<td>863 14.33%</td>
<td>2064 34.27%</td>
</tr>
<tr>
<td>Number of non-depressive symptoms</td>
<td>768 12.75%</td>
<td>3191 52.98</td>
<td>3959 65.73%</td>
</tr>
<tr>
<td>Total number</td>
<td>1969 32.69%</td>
<td>4054 34.27%</td>
<td>6023 5.42 &lt;0.05</td>
</tr>
</tbody>
</table>

Table 4 Changes in depression measurement factors in teenagers with or without NSSI behavior at baseline and follow-up
3.4 Binary Logistic Regression Analysis of NSSI that Affects Adolescents

Taking whether adolescents commit NSSI as a dependent variable while considering gender, age, depression measurement factors, duration of sleep, duration of exercise, duration of online class, self-perception of relationship with caregivers, residence, whether unemployed due to COVID-19, and whether they have a history of COVID-19 infection as the independent variables, a binary logistic regression analysis (forward: Wald method) was conducted on the NSSI behaviors of adolescents with or without depressive symptoms. The introduction level was 0.05 and the exclusion level was 0.1. The statistical results showed that among adolescents, gender, duration of the online class, depression mood, place of residence, and self-perception of relationship with caregivers were the risk factors for NSSI (or > 1, β > 0), and daily sleep hours positive mood was the protective factor (or < 1, β < 0). (Table 5)

Table 5 Results of binary Logistic regression analysis of influencing factors for NSSI
3.5 Relationship Between Depressive Symptoms and Self-injury among Adolescents

Using gender and age as control variables, the Cross-lagged analysis (using Mplus version 7.3) was utilized to explore the bidirectional relationship between depressive symptoms and NSSI. The model fit well with $X^2/df=2.74$, CFI=0.996, TLI=0.993, RMSEA=0.017. The presence of NSSI at baseline was a predictor of depressive symptoms at follow-up ($\beta=0.239$, $p<0.01$). Depressive symptoms at baseline were a predictor of NSSI at follow-up ($\beta=0.26$, $p<0.01$). The cross-lagged model also presented other structural pathways. Adolescent NSSI during the COVID-19 pandemic was significantly associated with prior NSSI ($\beta=0.43$, $p<0.05$), previous depressive symptoms were significantly associated with depressive symptoms during the COVID-19 pandemic ($\beta=0.53$, $p<0.001$). Self-injury was positively correlated with depressive symptoms at baseline and follow-up, with correlation coefficients of 0.77 ($p<0.05$) and 0.27 ($p<0.01$) respectively. (Figure 2). According to the data, there was a stable correlation between depression and NSSI ($\beta=0.53$, $p<0.05$ $\beta=0.43$, $p<0.05$). The lag effect of adolescent depression on their NSSI behavior is significant, which means that based on controlling the adolescent baseline NSSI, the deeper the adolescent depression degree, the more frequent their NSSI behavior ($\beta=0.26$, $p<0.01$). At the same time, adolescents’ NSSI behavior also had a lagging effect on depressive symptoms, and adolescents with self-injury behavior were more likely to be depressed ($\beta=0.02$, $p<0.01$). Depression and NSSI are mutual ($\beta=0.77$, $p<0.05$ $\beta=0.27$, $p<0.01$).

4. Discussion

The results showed that in the context of the COVID-19 pandemic, the number of adolescents with depressive symptoms increased significantly, and the NSSI behavior became more frequent as well. The occurrence rate of depression was 34.27%, showing an upward trend. The occurrence rate of NSSI accompanied by depressive symptoms among adolescents is 53.44%, also showing an upward trend. These findings enriched the theoretical research on teenage mental health and NSSI in the context of the COVID-19 pandemic. This study
proved that with an increased occurrence rate of NSSI among adolescents, future depressive symptoms and NSSI behaviors could be predicted by the change in depressive symptoms according to the passage of time.

The results of the deterioration of depressive symptoms and the increase in NSSI behaviors are consistent with our hypothesis of the COVID-19 pandemic's influence on adolescents' mental health. Depression will possibly trigger NSSI behaviors, and the persistence of NSSI behaviors will in turn aggravate depressive emotions. Studies indicate that any disasters will increase the risk of potential psychological and mental problems among sensitive individuals or ordinary individuals, one of the most common reactions psychologically is depression. In the general population, the development of psychiatric symptoms such as depression, distress, stress, and anxiety in individuals who have never experienced psychiatric illness was activated during COVID-19, while groups that are suffering psychologically may exacerbate pre-existing mental and emotional distress. Adolescents with depressive symptoms may develop higher levels of depression as a result of the epidemic (32.69% to 34.27%). Before the pandemic, there were studies suggesting that when one develops obnoxious feelings, such as depression or anxiety, they are more likely to commit self-harm behaviors.

Gender has been previously confirmed as one of the predictors of adolescents’ mental health during the COVID-19 pandemic, which was consistent with the results of this study. Female students seem to be more negatively affected by the pandemic. We speculate that, during the school closure period, female students are more likely to desire to bond with others, rely on peer relationships, and worry about being abandoned, feeling lonely, and loving relationships. Therefore, girls with depressive symptoms are more likely to have adverse emotional experiences during isolation. Studies also found that sleep duration is a vital and modifiable influential factor of NSSI. A study investigated 223 teenagers with self-injury behavior and found that 2% of the teenagers had serious sleep problems. It was proved that shorter sleep duration is directly related to depressive. According to the National Sleep Foundation, adolescents are encouraged to sleep 8e10 h per day. Sleep deprivation leads to reduced emotional regulation, which in turn triggers higher levels of depression and eventually leads to self-injurious behavior.

The teenager's self-perception of his/her relationship with caregivers should be considered as a predictor. Among all adolescents, the ones who view their relationship with their caregivers as bad are more vulnerable to NSSI. Studies indicate that Chinese parents’ rigid education method can increase the prevalence of NSSI among children. The dysfunction of the home environment can increase the risk of NSSI, and adverse factors such as inharmony between family members and emotional expression obstacles among family members are correlated with NSSI. During the pandemic, parents must support their children to study at home while working from home, and the duration of online classes is also one of the predictors of NSSI, which possibly raise the stakes of parent-young child conflict. Therefore, the increased burden and pressure on parents due to school closure is also on the rise, and students’ self-harm behaviors are affected.

The past theories about the psychological effects of approaching disasters have provided predictions about how an individual's residence should affect their mental health, namely "psychological typhoon eye". The results of this study support the psychological typhoon-eye effect because the risk of NSSI among adolescents living in rural areas is lower than that of adolescents living in urban areas, regardless of whether these adolescents have depressive symptoms. Our proposed potential explanation for this is the reduction of social contact among individuals. During this pandemic, all adolescents were forced to reduce social contact, and
compared with rural adolescents, involuntary reduction of social contact may cause more pain to socially active urban adolescents. Self-harm may also increase due to limited social contact, especially among those with mental vulnerability. I think technological advances (e.g., social media, texting, web conferencing platforms) that allow for greater social connection in the context of physical distance may impact these. Adolescents with psychological symptoms lack or passively receive treatment due to their own and external factors, among which the influential factors that cannot be ignored are the lack of mental health literacy or the lack of effective external support. Especially for adolescents suffering from mental illness or experiencing negative emotions, social media has become an important channel for them to find peers, communicate mental state and emotional experience, seek external support, and obtain self-identity and group identity.

Positive emotion is a positive predictor. Previous evidence has proved that disasters and epidemics can stimulate social cohesion and solidarity. For example, after the outbreak of severe acute respiratory syndromes in Hong Kong in 2003, residents' sense of belonging to their friends and family increased. Therefore, in the context of the COVID-19 pandemic, the widely shared anti-pandemic experience may strengthen social cohesion and intimacy, which may change the views of adolescents on death and health. Adolescents with psychological problems may feel the public support for the government's COVID-19 prevention strategies and control measures in an unfavorable environment, and the help of various social circles in providing survival and medical materials in the epidemic area, which may promote them to improve their psychological functions and experience positive psychological changes.

The study found that depressive symptoms were significantly correlated with NSSI of adolescents, and depressive symptoms before the pandemic could significantly positively predict depressive symptoms and NSSI during the pandemic, which confirmed the hypothesis of this study. The results of the study show that in a global crisis such as COVID-19, one should pay attention to adolescents’ mental health, which is practically significant for individuals, families, schools, and public policies, and provide practical and feasible intervention measures. Lastly, there are several limitations to this study. To start with, the duration between the two points of time of the longitudinal study is 7 months, which is short but reasonable, since we collected the data before and after the school closure in Chengdu. In addition, because this study uses a self-administered questionnaire to collect data, there may be some confounding factors in the study, such as recollection bias, report bias, etc., which may affect the stability of the longitudinal association of our study. Further improvement in future studies is in demand.

5. Conclusions

The depressive symptoms and NSSI behaviors of adolescents before COVID-19 and the depressive symptoms of adolescents during COVID-19 have exacerbated NSSI behaviors and had negative impacts on their mental health. Screening of depression should be conducted early to make proper preparation for reducing NSSI or suicides among adolescents. In the context of the COVID-19 pandemic, there is a longitudinal bidirectional relationship between depressive symptoms and NSSI in adolescents, and depressive symptom is an intrinsic and adjustable factor of NSSI. This study has made great contributions to the field of psychology, can fill the gap in the longitudinal research on teenage mental health, and is of great significance to the formulation of prevention and intervention measures for NSSI in the future.
abbreviations

<table>
<thead>
<tr>
<th>abbreviations</th>
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<tr>
<td>NSSI</td>
<td>Non-suicidal self-injury</td>
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<tr>
<td>CPCD</td>
<td>Chengdu Positive Child Development</td>
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<tr>
<td>DSHI</td>
<td>Deliberate Self-Harm Inventory</td>
</tr>
<tr>
<td>CES-DC</td>
<td>Center for Epidemiologic Studies Depression Scale for Children</td>
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<tr>
<td>SD</td>
<td>standard deviation</td>
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<tr>
<td>CFI</td>
<td>Comparative fit index</td>
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<tr>
<td>RMSEA</td>
<td>Root Mean Square Error of Approximation</td>
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<tr>
<td>TLI</td>
<td>Tucker-Lewis index</td>
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Declarations

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Authors’ contributions

**Rui Hu:** Writing Original Draft, Writing- Reviewing and Editing, Methodology, Data Curation, Investigation, Formal analysis.

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**Li Zhao:** Conceptualization, Methodology, Project administration, Funding acquisition.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to [reasons of sensitivity e.g. human data] but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration, and was approved by the Human Ethics Committee of Sichuan University and the registration number of which is K2020025. Written informed consent was obtained from individual or guardian participants.

Consent for publication

Not applicable.

Competing interests

The authors have no conflicts of interest to disclose.

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REFERENCES


**Figures**

**Figure 1**

Number of teenagers with possible depressive symptoms who developed NSSI at baseline and follow-up
Figure 2

The cross-lagged model between NSSI and depressive symptoms

b Note: Using sex and age as control variables, the bidirectional arrows in the figure present the correlation analysis results, and the number is the correlation coefficient; The one-way arrows present the path analysis results, and the number are standardized regression coefficients (β). * P<0.05. ** P<0.01. Depression W1: depressive symptoms at baseline; Depression W2: depressive symptoms at follow-up; NSSI W1: NSSI behavior at baseline; NSSI W2: NSSI behavior at follow-up.