AKADÉMIAI KIADÓ

Journal of Behavioral Addictions

DOI:
10.1556/2006.2023.00078

FULL-LENGTH REPORT

Mobile phone addiction and suicide behaviors among Chinese adolescents: The mediation of poor sleep quality

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Received: February 8, 2023 • Revised manuscript received: July 18, 2023; September 22, 2023 • Accepted: December 3, 2023

ABSTRACT

Background and aims: Mobile phone addiction (MPA) is emerging among adolescents, especially during the COVID-19 pandemic. Nevertheless, there is a dearth of knowledge regarding the correlation between MPA and suicide behaviors and its mechanism. The objective of the current study is exploring the direct effect of MPA on suicide behaviors and the indirect effect through poor sleep quality. *Methods:* A total of 18,900 Chinese adolescents aged 12 to 18 were recruited via a multi-stage cluster sampling method. *Results:* The prevalence of MPA and poor sleep quality was 26.2 and 23.1%, respectively. During the past year, 24.4% participants were involved in suicide behaviors. Specifically, suicide ideators, suicide planners, and suicide attempters were 10.7, 8.4, and 5.3%, respectively. Particularly, rural females had the highest prevalence of suicide behaviors, MPA, and poor sleep quality. Logistic regression analysis showed that MPA was significantly associated with suicide ideators (OR = 1.22, 95% CI: 1.09–1.37, $p < 0.001$) and planners (OR = 1.18, 95% CI: 1.04–1.34, $p < 0.05$), but not for suicide attempters ($p > 0.05$). Structural equation modelling demonstrated that MPA had direct effect on suicide behaviors ($\beta = 0.145$, 95% CI = 0.127–0.160), and poor sleep quality partially mediated the relationship (the mediating ratio was 46.7%). The mediating ratio of poor sleep quality was the highest in urban males. *Conclusions:* MPA has both direct and indirect effects on suicide behaviors. For suicide prevention, limited mobile phone use and improvement sleep quality may be practical for adolescents. Additionally, more efforts of intervention could give priority to rural girls.

KEYWORDS

mobile phone addiction, suicide behaviors, suicidal ideation, suicide attempts, poor sleep quality

INTRODUCTION

The amount of mobile phone users has reached 5 billion globally, and it is anticipated that this number will dramatically increase in the forthcoming years (Islam, 2021). In China, mobile phone users are over 1,028 million in 2021, and 13.3% of these population are adolescents between the ages of 10 and 19 years (Gao et al., 2022). Mobile phones have been an essential tool for communication, entertainment, and learning in our daily lives (Chen et al., 2016; Demirci, Akgönül, & Akpinar, 2015; Jasso-Medrano & López-Rosales, 2018). Simultaneously, excessive mobile phone use or mobile phone addiction has become an emerging global public health issue (Lee, Ahn, Min, & Kim, 2020; Liu et al., 2018; Ting & Chen, 2020). Mobile phone addiction (MPA) refers to the loss of regulation for mobile phone use, which could further lead to addictive symptoms similar to substance abuse disorders, including compulsive use, loss of control, withdrawal, cravings, and mood dysregulation

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(Billieux, Maurage, Lopez-Fernandez, Kuss, & Griffiths, 2015; Griffiths, Kuss, & Demetrovics, 2014). With the broad definition, it is also named as "problematic mobile phone use" or "smartphone addiction" in existing literature (Kim, 2022; Panova & Carbonell, 2018; Yang, Fu, Liao, & Li, 2020).

Compared to adults, adolescents may exhibit greater susceptibility to MPA since they lack a stable ability to regulate emotions and manage behaviors (Kim & Han, 2020; Li et al., 2019; Yang, Zhou, Liu, & Fan, 2019). The prevalence rate of MPA among children and adolescents has been estimated to be 10%–31% across countries around the world (Ting & Chen, 2020), and the rate is still rising rapidly (Li et al., 2019; Liu et al., 2018). In particular, COVID-19 has compelled many countries across the globe to implement quarantine procedures, such as lockdowns, social distancing, self-isolation, and staying home (Bedford et al., 2020). Many high school students are forced to have online classes via mobile phones or Pads at home during the COVID-19 pandemic (Islam, 2021). Consequently, there is a great increase of mobile phone use in students, which could result in the emerging prevalence of MPA (Duan et al., 2021; Kim, 2022; Li, Zhan, Zhou, & Gao, 2021). For example, many Chinese students must have online classes at home via smartphones or Pads rather than computers, which could result in an emerging prevalence of MPA during the COVID-19 pandemic (Duan et al., 2021; Kim, 2022; Li et al., 2021). More importantly, growing evidence has found that MPA is related to various adverse outcomes (Kim & Han, 2020; Xie, Dong, & Wang, 2018), such as emotional or psychological problems (i.e. depressive symptoms, anxiety, and suicidality) (Chen et al., 2016; Elhai, Levine, Dvorak, & Hall, 2017; Gao et al., 2022; Kim & Han, 2020), poor sleep quality (Demirci et al., 2015; Yang et al., 2020), poor academic performance (Kuss & Griffiths, 2011; Samaha & Hawi, 2016), and physical health problems (i.e. cardiovascular diseases and obesity) (Lissak, 2018). However, compared to ample research conducted in college students or young adults (Chen et al., 2016; Demirci et al., 2015; Huang et al., 2022; Ismail et al., 2020; Jasso-Medrano & López-Rosales, 2018; Okasha et al., 2021; Shi, Zhai, Li, Shi, & Fan, 2021; Zhao et al., 2021), only a few studies related to MPA conducted in high school students or adolescents (Jin Jeong et al., 2020; Kim & Han, 2020; Liu et al., 2017). Therefore, it is necessary for more research to enhance our ability to detect the epidemiological characteristics and detrimental effects of MPA in adolescents.

Mobile phone addiction and suicide behaviors

To date, few studies have examined whether MPA could subsequently predict suicide behaviors among adolescents (Li, Conti, Qiu, & Tang, 2022; Sohn, Oh, Lee, & Potenza, 2017). Nowadays, it is well-accepted that suicide behaviors are a developmental continuum, encompassing four distinct phases from beginning to end: suicide ideation, suicide plans, suicide attempts, and suicide death (Qu et al., 2021; Sveticic & De Leo, 2012). MPA could grow difficulties in self-control, both mentally and physically, which can cause adolescents to have suicidal ideation, and even attempt suicide (Ismail et al., 2020; Li et al., 2022). Recently, Shinetsetseg et al. revealed that adolescents with problematic mobile phone use had about twice risk odds of suicidal ideation and attempts when compared to those general mobile phone users (Shinetsetseg, Jung, Park, Park, & Jang, 2022). However, Hyesun Kim found an incongruent finding among 25,987 Korean high school students that smartphone overdependence had significant effects on suicidal ideation and plans, but not on suicide attempts (Kim, 2022). Given the inconsistent findings from previous studies, it is reasonable to further clarify the relationships between MPA and suicidal ideation, suicide plans, and suicide attempts in context of different social and cultural backgrounds. To the best of our knowledge, few prior work has focused on Chinese adolescents or high school students.

Poor sleep quality as mediator

In addition to suicide behaviors, poor sleep quality has been identified as another key adverse outcome of MPA (Demirci et al., 2015; Liu et al., 2017; Tao et al., 2017; Yang et al., 2020). Poor sleep quality refers to difficulty falling asleep and/or maintaining sleep, generally as a feature of chronic insomnia and complex sleep phenomena (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Previous studies have indicated that individuals with higher levels of problematic mobile phone use could have increased risk of insomnia, excessive daytime sleepiness, and short sleep duration (De-Sola Gutiérrez, Rodríguez de Fonseca, & Rubio, 2016). For adolescents, excessive mobile phone use could result in inadequate learning time, delayed study progress, and poor academic achievement (Zhang, Li, Fan, Tang, & Zhang, 2021). Consequently, these stress and failure will further lead to poor sleep quality (Cain & Gradisar, 2010; Zhang et al., 2021).

Beyond to MPA, poor sleep quality is also an important predictor of suicide behaviors (Wojnar et al., 2009; Wong, Brower, & Zucker, 2011). The relative risks between poor sleep quality and suicidal ideation, suicide attempts, and suicide ranged from 1.95 to 2.95 times (Pigeon, Pinquart, & Conner, 2012). In school-aged Chinese adolescents, poor sleep quality in baseline was related to an increased risk of suicidal ideation and plans after 2 years follow-up in boys, but the associations were not significant in girls (Gong, Li, Wang, Li, & Han, 2020). Therefore, it is sound to hypothesis that poor sleep quality could mediate the relationship between MPA and suicide behaviors. A recent longitudinal study based on 1,609 high school students in Sichuan province of China revealed that daytime sleepiness played the mediating effect between MPA and suicidality, which is one of the most common sequelae of poor sleep quality (Li et al., 2022). Another study conducted in 20,895 high school students in Guangdong province of China found that problematic Internet use has detrimental impact on suicidal ideation attempts through the mediation of sleep disturbance (Guo et al., 2018). Nevertheless, there is scarce empirical studies to explore

the mediation of poor sleep quality between MPA and three phases of suicide behaviors before death, including suicidal ideation, plans, and attempts. Moreover, it is worth noting that some prior studies generally recruited a small-size sample and/or a sample from a single province or city, thereby the findings are hard to generalize for adolescents around China. Therefore, it has great significance to recruit a representative sample and/or a large-size sample in Chinese adolescents for exploring the underlying mechanisms of suicide behaviors, which could help us to develop specific and efficient interventions for adolescents' suicide (Tymofiyeva et al., 2020).

Potential difference of sex and residence

Prior work presents some controversial findings with regard to sex differences in prevalence or risk odds of suicide behaviors. For instance, Guo et al. observed that Chinese boys had lower risks of suicidal ideation (OR = 0.61, 95% CI: 0.57–0.67) and suicide attempts (OR = 0.67, 95% CI: 0.56–0.79) than Chinese girls (Guo et al., 2018). Moreover, some other studies in different populations have demonstrated a congruent finding (Guo et al., 2020; Liu, Chen, Liu, Wang, & Jia, 2019; Shinetsetseg et al., 2022). However, according to data from mortality surveillance system, Chinese females had a lower incident rate ratio (IRR) of suicide rates (IRR = 0.79, 95% CI: 0.75–0.83) than Chinese males (Sha, Chang, Law, Hong, & Yip, 2018). Until now, there is a dearth of research exploring the difference of suicide behaviors between Chinese adolescents in different place of residence. While aforementioned information is helpful and useful to screen high risk population of suicide behaviors. Therefore, it is crucial to take into account the confounding influence of sex and residence in the relationship between MPA and suicide behaviors.

The current study

In order to address the gaps mentioned above, we conducted a cross-sectional study based on a large-size sample of high school students across five Chinese provinces. The first aim of the current study is to explore the independent effect of MPA on suicide behaviors. We speculated that MPA could significantly increase the risk odds of suicidal ideation, plans, and attempts (Hypothesis 1). Then, the second purpose is to examine the indirect effect of MPA on suicide behaviors. We anticipated that poor sleep quality could mediate the relationship between MPA and suicide behaviors (Hypothesis 2). Last, since there are debatable findings about the risk of suicide behaviors between males and females (Guo et al., 2018; Li et al., 2022; Shinetsetseg et al., 2022), and there is no previous study to compare the difference of MPA between urban and rural adolescents. Thus, our third objective is to explore the interaction of sex and residence. We expected that the direct and/or indirect effects of MPA on suicide behaviors might differ between urban male, urban female, rural male, and rural female participants (Hypothesis 3).

METHODS

Procedure and participants

A multi-stage cluster sampling method was conducted from April to December, 2021. The procedure of sampling consisted of five stages. In Stage 1, China was partitioned into five geographical divisions, namely central, eastern, southern, western, and northern areas. One representative province was chosen randomly from each selected area (Fig. 1). More detailed information regarding Stage 2 to Stage 5 was described in our other publication (Peng et al., 2023).

Fig. 1. Five selected provinces from the eastern, southern, western, northern, and central China

Of 21,207 students who submitted the questionnaire, 831 were excluded due to the age was over 18 or under 12 years old, 952 were excluded due to they provided no information concerning suicide behaviors, 524 were excluded because the missing data was over 15% of all variables in the current study. Eventually, 18,900 participants' questionnaire were qualified in the final analysis and the response rate was 89.12% (18,900/21,207).

Measurements

Suicidal behaviors were measured by using three related items according to the Global School-Based Student Health Survey, including suicide ideation, plans, and attempts (Ma et al., 2021). Specifically, suicide ideation: "Have you ever had serious thoughts of killing yourself during the past year?" Suicide plans: "Have you ever made a specific plan about how to kill yourself during the past year?" Suicide attempts: "Have you ever tried to kill yourself during the past year?" The response of these questions were dichotomized as No (0 times) vs. Yes (1 or more times) (Lee et al., 2021; Wan et al., 2019; Yang et al., 2020). As suicide behaviors are a developmental process, there is a skip logic for these three items (Sveticic & De Leo, 2012). If the response of suicide ideation is "Yes", these participants have to answer the question about suicide plans. Otherwise, the survey for suicide behaviors is finished. When the response of suicide plans is "Yes", these respondents must further give a response for suicide attempts. Then, we classified participants into four mutually exclusive groups of suicide behaviors: none group (participants without suicide ideation, plans, and attempts), suicide ideators (participants only have suicide ideation, neither plans nor attempts), suicide planners (participants have both suicide ideation and plans, but no suicide attempts), suicide attempters (participants simultaneously have suicide ideation, plans, and attempts) (Sveticic & De Leo, 2012; L. Wang, He et al., 2014).

The Mobile phone Addiction Index (MPAI) was used to measure mobile phone addiction (MPA) (Leung, 2008; Liu et al., 2017). The MPAI consists of 17 items and each item is scored on a 5-point Likert scale. The total score of MPAI ranged from 17 to 85. A higher score reveals a greater severity of MPA. In addition, according to Young's recommendation, Item 3, 4, 5, 6, 8, 9, 14, and 15 could be used to screen MPA, which are equivalent to the 8-item Young's Internet Addiction Diagnostic Questionnaire (YDQ) (Leung, 2008). YDQ had good reliability and validity in the previous studies (Johansson & GÖTestam, 2004; Yao, Han, Zeng, & Guo, 2013). If the participants responded to 5 or more items with a score of 3–5 in MPAI, they were considered having MPA (1 = yes) (Shi et al., 2021). The others were treated as having no MPA (0 = no). The Cronbach's α coefficient of the MPAI was 0.929 in this study.

The Pittsburgh Sleep Quality Index (PSQI) is a widely used scale globally to assess individuals' sleep quality during the past month (Buysse et al., 1989). The validated Chinese PSQI consists of 18 items. Total score of PSQI ranged from 0 to 21, with higher score indicating poorer sleep quality. In addition, the cut-off score of 8 is usually dichotomized for poor sleep quality in China (Huang et al., 2022). Prior studies have proved that the Chinese PSQI has good reliability and validity in Chinese population (Zhang, Xu, Zhu, & Zhong, 2017). The Cronbach α coefficient of the PSQI was 0.811 in our present study.

The control variables in the current study included depression, anxiety, smoking, and drinking alcohol (Li et al., 2022; Shi et al., 2021). The nine-item Patient Health Questionnaire (PHQ-9) was used to measure major depression disorders. Each item has a score ranging from 0 to 3 and total score ranges from 0 to 27. In the present study, the Cronbach's alpha of the PHQ-9 was 0.903. The seven-item Generalized Anxiety Disorder Scale (GAD-7) was used to screen generalized anxiety disorders. Each item has a score ranging from 0 to 3 and total score ranges from 0 to 21. In this study, the alpha Cronbach for the GAD-7 was 0.938. Smoking (yes or no) and drinking alcohol (yes or no) were measured through a question separately: Have you ever smoking (drinking alcohol) in the last 30 days (Guo et al., 2018)?

Statistical analysis

First, the Chi-square test was used to assess the difference of suicide behaviors by categorical variables, such as sex and residence. One-way ANOVA was used to compare the mean scores of MPAI, PSQI, PHQ-9, GAD-7, and age between four groups of suicide behaviors. Second, for examining the independent effects of MPA and poor sleep quality on suicide behaviors, multinomial logistic regression analysis was performed. We included MPA and poor sleep quality (0 = No, 1 = Yes) as two independent variables. The dependent variable was the involvement of suicide behaviors (0 = None, 1 = Suicide ideator, 2 = Suicide planner, 3 = Suicide attempter). Besides, we included smoking, drinking alcohol, depression (PHQ-9 score) and anxiety (GAD-7 score) and some demographic characteristics as confounding variables, which were significantly related to suicide behaviors involvement according to the chi-square test. The significance level was set at $p < 0.05$. These analyses mentioned above were conducted by IBM SPSS, version 26.0.

Third, we performed a set of structural equation modelling (SEM) to evaluate the mediating effects of sleep quality (PSQI score) between mobile phone addiction (MAPI score) and suicide behaviors by using IBM SPSS Amos 21.0. In model 1, we performed SEM without covariates. In model 2, we conducted SEM with some covariates, which were associated significantly with suicide behaviors in the multinomial logistic regression analysis. Then, in order to assess the underlying influence of sex × residence in the mediation model, we ran the two models of SEM for urban males, urban females, rural males, and rural females, separately.

Ethics

The study procedures were carried out according to the Declaration of Helsinki. The study was approved by the

Medical Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (2021-A216). Informed written consent was obtained from every participant and their guardians before the filed investigation.

RESULTS

Sample information

Among 18,900 participants, 9,416 (49.8%) were males, 9,880 (52.3%) were from urban areas, 9,970 (52.8%) were junior high school students, over four fifths (83.0%) were living with two biological parents. The mean (SD) of age was 14.99 (1.64). Other demographic characteristics were depicted in Table 1. In addition, 4,958 (26.2%) of participants reported mobile phone addiction (MPA), 4,357 (23.1%) had poor sleep quality during the last month, 4,605 (24.4%) were involved in suicide behaviors during the past year. Specifically, 2,016 (10.7%) were suicide ideators, 1,583 (8.4%) were suicide planners, and 1,006 (5.3%) were suicide attempters. Besides, 666 (3.5%) of Chinese adolescents reported smoking, and 1,574 (8.3%) reported drinking alcohol in the last 30 days (Table 1).

Univariate analysis of suicide behaviors

Compared to participants without MPA, participants with MPA reported a higher prevalence of suicide behaviors (38.7% vs. 19.3%, $p < 0.001$). Participants with poor sleep quality had a higher prevalence of suicide behaviors than those who without (44.8% vs. 18.2%, $p < 0.001$). Females reported more suicide behaviors than males (30.4% vs. 18.3%, $p < 0.001$). Rural adolescents reported more suicide behaviors than urban counterparts (25.7% vs. 23.1%, $p < 0.001$). The proportion of suicide ideators, planners, and attempters was significantly different in terms of all variables, except for father and mother's education (Table 1).

Logistic regression analysis of suicide behaviors

Compared to participants without MPA, those who with MPA had greater odds of being suicide ideators (OR = 1.22, 95% CI = 1.09–1.37) and suicide planners (OR = 1.18, 95% CI = 1.04–1.34). Participants with poor sleep quality had higher odds of being suicide ideators (OR = 1.21, 95% CI = 1.07–1.36), suicide planners (OR = 1.35, 95% CI = 1.18–1.54), and suicide attempters (OR = 1.65, 95% CI = 1.40–1.94). Females had greater risks of being suicide ideators (OR = 1.59, 95% CI = 1.44–1.76), suicide planners (OR = 1.71, 95% CI = 1.52–1.92), and suicide attempters (OR = 1.88, 95% CI = 1.62–2.19) than males. Rural adolescents had increased odds ratios of being suicide ideators (OR = 1.12, 95% CI = 1.01–1.25), suicide planners (OR = 1.14, 95% CI = 1.01–1.29), and suicide attempters (OR = 1.33, 95% CI = 1.14–1.56) than urban adolescents. Besides, age, drinking alcohol, PHQ-9 score, and GAD-7 score were significantly associated with all suicide behaviors involvement (Table 2).

The difference of sex × residence

Compared to males, females had higher prevalence of MPA and poor sleep quality ($p < 0.001$). Compared to urban adolescents, rural adolescents had higher prevalence of MPA and poor sleep quality ($p < 0.001$). With regard to sex × residence, rural females had the highest prevalence of MPA (31.3%) according to pairwise comparison, while urban males had the lowest (21.5%). The prevalence of MPA was not significantly different between urban females (25.6%) and rural males (27.0%). Besides, the prevalence of poor sleep quality from high to low among participants of sex × residence was similar to the prevalence of MPA (Table 3).

The mediating effect of sleep quality between mobile phone addiction and suicide behaviors

After controlling for covariates, there were direct effects of MPA ($\beta = 0.145$, 95% CI = 0.127–0.160) and sleep quality ($\beta = 0.294$, 95% CI = 0.276–0.310) on suicide behaviors. The total effect of MPA on suicide behaviors was 0.272 (95% CI = 0.255–0.288) and the indirect effect was 0.127 (95% CI = 0.118–0.135) (Fig. 2). The mediation ratio was 46.7%. In four groups, the mediation ratios of poor sleep quality between MPA and suicide behaviors from high to low were 55.3% (urban male), 45.0% (rural female), 41.7% (rural male), and 38.9% (urban female), respectively (Table 4).

DISCUSSION

In the current study, we first explore the direct and indirect effects of mobile phone addiction (MPA) on suicide ideation, plans, and attempts in Chinese adolescents. There are multiple novel and significant findings. First, there is a direct effect of MPA on suicide behaviors. Concerning different involvement of suicide behaviors, MPA is significantly associated with suicide ideators and planners, but not with suicide attempters. Second, MPA also has an indirect effect on suicide behaviors, with a mediating role of poor sleep quality. Third, the effects may differ between boys and girls in urban and rural China. Although rural girls have the highest prevalence of suicide behaviors, MPA, and poor sleep quality, the mediating effect of poor sleep quality may be the strongest in urban boys. These findings advance our understanding of the development of adolescents' suicide behaviors, which is beneficial for scholars, social workers, and policy-makers to develop targeted prevention for suicide.

The prevalence of mobile phone addiction

Although the majority of Chinese high schools students are prohibited from bring mobile phones to school, they were forced to switch to online learning on and off due to the COVID-19 pandemic. Under that circumstance, even though some students didn't have their own mobile phones or Pads, parents had to allow their children to use mobile phones for online classes. This situation could facilitate the

Table 1. General characteristics of participants and proportion of suicide behaviors

Variables	Total	Suicide behaviors				χ^2/F value	*p* value
		None	Suicide ideator	Suicide planner	Suicide attempter		
Mobile phone addiction						772.54	<0.001
No	13,942 (73.8)	11,257 (80.7)	1,241 (8.9)	893 (6.4)	551 (4.0)		
Yes	4,958 (26.2)	3,038 (61.3)	775 (15.6)	690 (13.9)	455 (9.2)		
Poor sleep quality						1,413.47	<0.001
No	14,543 (76.9)	11,892 (81.8)	1,302 (9.0)	877 (6.0)	472 (3.2)		
Yes	4,357 (23.1)	2,403 (55.2)	714 (16.4)	706 (16.2)	534 (12.3)		
Sex						372.83	<0.001
Male	9,416 (49.8)	7,690 (81.7)	778 (8.3)	586 (6.2)	362 (3.8)		
Female	9,484 (50.2)	6,605 (69.6)	1,238 (13.1)	997 (10.5)	644 (6.8)		
Residence						18.70	<0.001
Urban	9,880 (52.3)	7,593 (76.9)	1,008 (10.2)	765 (7.7)	514 (5.2)		
Rural	9,020 (47.7)	6,702 (74.3)	1,008 (11.2)	818 (9.1)	492 (5.5)		
Grade						52.30	<0.001
7th – 9th	9,970 (52.8)	7,555 (75.8)	978 (9.8)	811 (8.1)	626 (6.3)		
10th – 12th	8,930 (47.2)	6,740 (75.5)	1,038 (11.6)	772 (8.6)	380 (4.3)		
Family composition						144.83	<0.001
Two biological parents	15,690 (83.0)	12,083 (77.0)	1,651 (10.5)	1,226 (7.8)	730 (4.7)		
Single biological parent	2,127 (11.3)	1,462 (68.7)	240 (11.3)	246 (11.6)	179 (8.4)		
Others	1,009 (5.3)	692 (68.6)	118 (11.7)	105 (10.4)	94 (9.3)		
Missing data	74 (0.4)	–	–	–	–		
Father's education						13.24	0.189
Primary school or less	1,819 (9.6)	1,362 (74.9)	184 (10.1)	170 (9.3)	103 (5.7)		
Junior high school	7,148 (37.8)	5,447 (76.2)	763 (10.7)	581 (8.1)	357 (5.0)		
Senior high school	5,433 (28.7)	4,132 (76.1)	560 (10.3)	432 (8.0)	309 (5.7)		
College or more	4,353 (23.0)	3,243 (74.5)	491 (11.3)	388 (8.9)	231 (5.3)		
Missing data	147 (0.8)	–	–	–	–		
Mother's education						14.92	0.093
Primary school or less	3,147 (16.7)	2,352 (74.7)	358 (11.4)	279 (8.9)	158 (5.0)		
Junior high school	7,098 (37.6)	5,459 (76.9)	701 (9.9)	565 (8.0)	373 (5.3)		
Senior high school	4,856 (25.7)	3,666 (75.5)	517 (10.6)	410 (8.4)	263 (5.4)		
College or more	3,612 (19.1)	2,682 (74.3)	418 (11.6)	311 (8.6)	201 (5.6)		
Missing data	187 (1.0)	–	–	–	–		
Family income (RMB)						34.67	0.001
8,000 ~	4,528 (24.0)	3,461 (76.4)	469 (10.4)	336 (7.4)	262 (5.8)		
6,000–7,999	3,463 (18.3)	2,663 (76.9)	326 (9.4)	294 (8.5)	180 (5.2)		
4,000–5,999	4,559 (24.1)	3,478 (76.3)	473 (10.4)	370 (8.1)	238 (5.2)		
2000–3,999	3,858 (20.4)	2,848 (73.8)	467 (12.1)	345 (8.9)	198 (5.1)		
~1,999	2,133 (11.3)	1,566 (73.4)	247 (11.6)	207 (9.7)	113 (5.3)		
Missing data	359 (1.9)	–	–	–	–		
Smoking						212.65	<0.0001
No	18,234 (96.5)	13,899 (76.2)	1951 (10.7)	1,487 (8.2)	897 (4.9)		
Yes	666 (3.5)	396 (59.5)	65 (9.8)	96 (14.4)	109 (16.4)		
Drinking alcohol						318.62	<0.001
No	17,326 (91.7)	13,357 (77.1)	1795 (10.4)	1,373 (7.9)	801 (4.6)		
Yes	1,574 (8.3)	938 (59.6)	221 (14.0)	210 (13.3)	205 (13.0)		
Age, M (SD)	14.99 (1.64)	14.99 (1.65)	15.09 (1.58)	15.00 (1.58)	14.65 (1.55)	17.22	<0.001
MPAI, M (SD)	36.51 (14.90)	34.21 (13.95)	41.91 (14.19)	44.91 (15.59)	45.17 (17.39)	522.70	<0.001
PSQI, M (SD)	5.57 (2.99)	5.01 (2.71)	6.74 (2.76)	7.48 (3.02)	8.27 (3.67)	868.01	<0.001
PHQ-9, M (SD)	5.54 (5.73)	4.06 (4.53)	8.40 (5.61)	10.75 (6.36)	12.56 (7.68)	1837.62	<0.001
GAD-7, M (SD)	4.23 (5.20)	2.98 (4.15)	6.72 (5.40)	8.63 (6.05)	10.11 (6.90)	1,540.48	<0.001
Total	18,900 (100.0)	14,295 (75.6)	2,016 (10.7)	1,583 (8.4)	1,006 (5.3)		

MPAI: The Mobile phone Addiction Index; PSQI: The Pittsburgh Sleep Quality Index; PHQ-9: The nine-item Patient Health Questionnaire; GAD-7: The seven-item Generalized Anxiety Disorder Scale.

excessive use of mobile phones (Islam, 2021). According to our results, the prevalence of MPA in Chinese high school students is 26.2%. Generally, the prevalence of MPA varies greatly (from 10% to 31%) in previous studies conducted in different countries and populations (Ting & Chen, 2020). The difference may stem from different tools or criteria of

Table 2. Multinomial logistic regression of suicide behaviors [OR (95% CI)]

Variables	Suicide behaviors		
	Suicide ideator	Suicide planner	Suicide attempter
Mobile phone addiction			
No	1.00	1.00	1.00
Yes	1.22 (1.09, 1.37)***	1.18 (1.04, 1.34)*	1.06 (0.90, 1.24)
Poor sleep quality			
No	1.00	1.00	1.00
Yes	1.21 (1.07, 1.36)**	1.35 (1.18, 1.54)***	1.65 (1.40, 1.94)***
PHQ-9 score	1.11 (1.09, 1.13)***	1.16 (1.14, 1.18)***	1.18 (1.16, 1.21)***
GAD-7 score	1.05 (1.04, 1.07)***	1.07 (1.05, 1.08)***	1.07 (1.05, 1.09)***
Smoking			
No	1.00	1.00	1.00
Yes	0.74 (0.55, 1.01)	1.28 (0.96, 1.72)	2.10 (1.54, 2.86)***
Drinking alcohol			
No	1.00	1.00	1.00
Yes	1.43 (1.19, 1.71)***	1.40 (1.14, 1.71)**	1.90 (1.52, 2.38)***
Sex			
Male	1.00	1.00	1.00
Female	1.59 (1.44, 1.76)***	1.71 (1.52, 1.92)***	1.88 (1.62, 2.19)***
Residence			
Urban	1.00	1.00	1.00
Rural	1.12 (1.01, 1.25)*	1.14 (1.01, 1.29)*	1.33 (1.14, 1.56)***
Age	0.91 (0.85, 0.96)**	0.86 (0.80, 0.92)***	0.86 (0.80, 0.92)***
Family composition			
Two biological parents	1.00	1.00	1.00
Single biological parent	1.04 (0.89, 1.22)	1.28 (1.09, 1.52)**	1.53 (1.25, 1.87)***
Others	0.96 (0.77, 1.20)	1.04 (0.81, 1.32)	1.46 (1.12, 1.90)**
Father's education			
Primary school or less	1.00	1.00	1.00
Junior high school	1.25 (1.03, 1.51)*	0.99 (0.81, 1.22)	0.92 (0.71, 1.19)
Senior high school	1.20 (0.98, 1.48)	0.98 (0.78, 1.23)	1.07 (0.80, 1.42)
College or more	1.25 (0.99, 1.58)	1.07 (0.83, 1.39)	0.90 (0.65, 1.24)
Family income (RMB)			
8,000 ~	1.00	1.00	1.00
6,000–7,999	0.88 (0.75, 1.03)	1.07 (0.89, 1.28)	0.81 (0.65, 1.01)
4,000–5,999	0.96 (0.83, 1.12)	1.01 (0.85, 1.20)	0.80 (0.65, 0.99)*
2,000–3,999	1.12 (0.96, 1.30)	1.10 (0.92, 1.32)	0.78 (0.62, 0.97)*
~1,999	0.95 (0.79, 1.15)	1.00 (0.81, 1.25)	0.68 (0.52, 0.90)**

The reference category for the dependent variable was the None group (without suicide ideation, plans, and attempts).
Model fit statistics: chi-square value was 4,587, $p < 0.001$, $R^2 = 0.154$.
Insignificant variables were grade and mother's education.
PHQ-9: The nine-item Patient Health Questionnaire; GAD-7: The seven-item Generalized Anxiety Disorder Scale.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

measurement (Chen et al., 2016; Li et al., 2019; Yang et al., 2020). For example, the Mobile phone Addiction Index (MPAI) is the most common scale to screen MPA and its total score ranges from 17 to 85 (Leung, 2008). Some studies take 51 as the cut-off value of having MPA or not, while others take 60 (Gao et al., 2022; Li et al., 2022). However, we took another measure approach of MPAI, which is consistent with the Young's Internet Addiction Diagnosis Questionnaire (Young, 1998). The approach has been validated in some empirical research (Shi et al., 2021; Zhao et al., 2021).

Our results indicated that female adolescents have a significantly higher prevalence of MPA than male adolescents, which is consistent with existing findings (Demirci et al., 2015; Jin Jeong et al., 2020; Shi et al., 2021). A possible explanation for the sex difference is that females have more social and emotional motives for mobile phone use, while males have more utilitarian and entertainment motives for computer use (Roberts, Yaya, & Manolis, 2014; Ting & Chen, 2020; Tymofiyeva et al., 2020). Moreover, our study disclosed that rural adolescents have a higher prevalence of MPA than urban adolescents. This finding extends the existing literature regarding the epidemiological characteristics of MPA. In rural China, there are a large account of left-behind children/adolescents (25%–43%), whose one or two of parents have left from their hometown for work (Chang et al., 2017; Peng et al., 2021). Generally, mobile phones have become the bridge of communications between parents in towns and their left-behind children in villages.

Table 3. The prevalence of mobile phone addiction and poor sleep quality among participants of sex × residence

Variables	*n* (%)	Mobile phone addiction		n (%)	Poor sleep quality	
		χ^2 value	*p* value		χ^2 value	*p* value
Sex		53.94	<0.001		128.88	<0.001
Male (*n* = 9,416)	2,248 (23.9)			1,842 (19.6)		
Female (*n* = 9,484)	2,710 (28.6)			2,515 (26.5)		
Residence		87.65	<0.001		88.86	<0.001
Urban (*n* = 9,880)	2,309 (23.4)			2,005 (20.3)		
Rural (*n* = 9,020)	2,649 (29.4)			2,352 (26.1)		
Sex £ Residence		131.13	<0.001		203.53	<0.001
Urban Male (*n* = 5,313)	1,140 (21.5)			939 (17.7)		
Urban Female (*n* = 4,567)	1,169 (25.6)			1,066 (23.3)		
Rural Male (*n* = 4,103)	1,108 (27.0)			903 (22.0)		
Rural Female (*n* = 4,917)	1,541 (31.3)			1,449 (29.5)		
Pairwise comparison						
	d > c	20.27	<0.001	d > c	64.59	<0.001
	d > b	38.27	<0.001	d > b	45.63	<0.001
	d > a	93.13	<0.001	d > a	198.56	<0.001
	c > b	2.21	0.137	b > c	2.19	0.139
	c > a	22.08	<0.001	b > a	48.77	<0.001
	b > a	10.65	0.001	c > a	27.64	<0.001

a: Urban Male, b: Urban Female, c: Rural Male, d: Rural Female in pairwise comparison (Chi-square test).

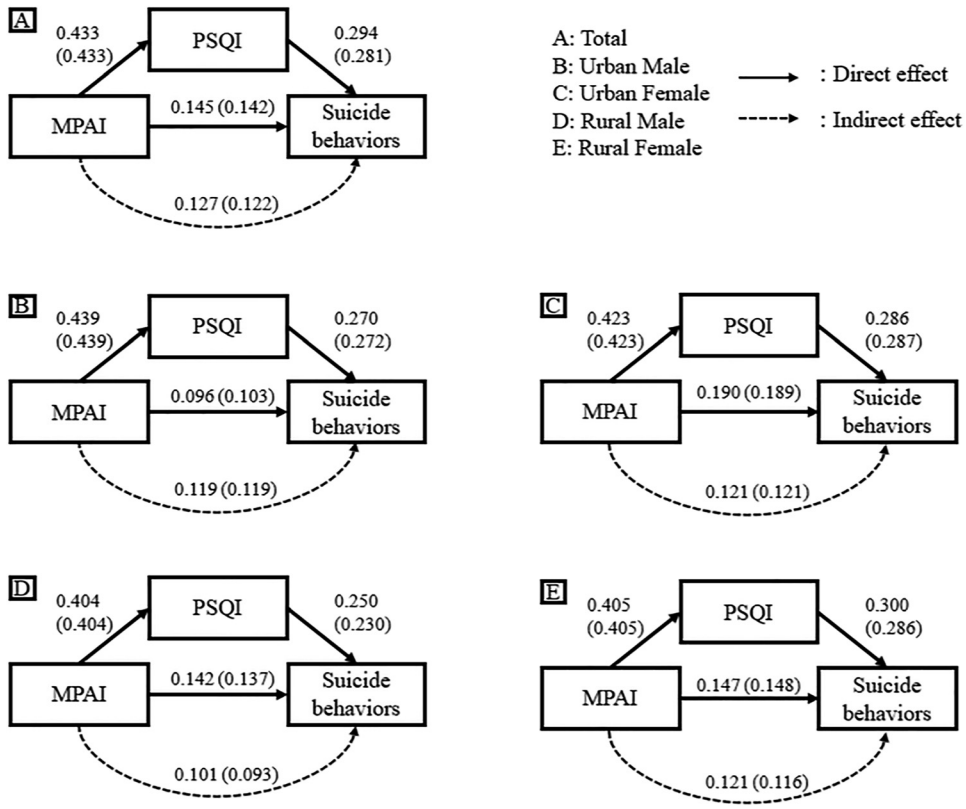

Fig. 2. Structural equation modelling depicting the mediating effect of poor sleep quality (PSQI score) between mobile phone addiction (MPAI score) and suicide behaviors. MPAI: The Mobile phone Addiction Index; PSQI: The Pittsburgh Sleep Quality Index. Adjusted coefficients β (unadjusted coefficients β without covariates) are presented. Adjusted for some significant covariates in the logistic regression analysis of suicide behaviors. The significance of all standardized β estimate was <0.05

Apart from sound or video communication with migrated parents via mobile phone, left-behind children have more access to mobile phone use without parental supervision. This might be the main reason why the prevalence of MPA in rural adolescents is significantly higher than that in urban adolescents.

Table 4. Mediating effect of poor sleep quality (PSQI score) between mobile phone addiction (MPAI score) and suicide behaviors [Standardized β estimate (95% CI)]

Groups	Direct effect			Indirect effect	Total effect	Mediating ratio,%
	Path 1	Path 2	Path 3			
Model 1						
Total	0.142 (0.124, 0.157)	0.281 (0.264, 0.296)	0.433 (0.420, 0.445)	0.122 (0.113, 0.129)	0.264 (0.247, 0.277)	46.2
Urban male	0.103 (0.066, 0.132)	0.272 (0.238, 0.301)	0.439 (0.411, 0.466)	0.119 (0.104, 0.135)	0.222 (0.190, 0.250)	53.6
Urban female	0.189 (0.157, 0.222)	0.287 (0.250, 0.316)	0.423 (0.396, 0.450)	0.121 (0.102, 0.135)	0.310 (0.285, 0.337)	39.0
Rural male	0.137 (0.096, 0.183)	0.230 (0.183, 0.277)	0.404 (0.373, 0.437)	0.093 (0.076, 0.116)	0.230 (0.189, 0.266)	40.4
Rural female	0.148 (0.114, 0.179)	0.286 (0.249, 0.324)	0.405 (0.374, 0.435)	0.116 (0.099, 0.135)	0.264 (0.234, 0.296)	43.9
Model 2						
Total	0.145 (0.127, 0.160)	0.294 (0.276, 0.310)	0.433 (0.420, 0.445)	0.127 (0.118, 0.135)	0.272 (0.255, 0.288)	46.7
Urban male	0.096 (0.057, 0.127)	0.270 (0.235, 0.302)	0.439 (0.411, 0.466)	0.119 (0.101, 0.135)	0.215 (0.180, 0.246)	55.3
Urban female	0.190 (0.157, 0.224)	0.286 (0.249, 0.317)	0.423 (0.396, 0.450)	0.121 (0.104, 0.136)	0.311 (0.285, 0.339)	38.9
Rural male	0.142 (0.103, 0.186)	0.250 (0.205, 0.300)	0.404 (0.373, 0.437)	0.101 (0.084, 0.123)	0.242 (0.205, 0.279)	41.7
Rural female	0.147 (0.113, 0.182)	0.300 (0.262, 0.336)	0.405 (0.374, 0.435)	0.121 (0.105, 0.140)	0.269 (0.242, 0.301)	45.0

Note. MPAI: The Mobile phone Addiction Index; PSQI: The Pittsburgh Sleep Quality Index.
Path 1: Mobile phone addiction → suicide behaviors, Path 2: Poor sleep quality → suicide behaviors, Path 3: Mobile phone addiction → Sleep quality.
Model 1: Unadjusted for covariates, Model 2: Adjusted for significant covariates in the logistic regression analysis of suicide behaviors.
The significance of all standardized β estimate was <0.05.

Considering the two factors concurrently, sex and residence, it is not surprising that rural females have the highest prevalence of MPA while urban males have the lowest. This may be due to the fact that rural girls have the fewest social activities in four groups. To ensure safety, most girls in rural China may be prohibited by their guardians from socializing unless they have permission. On the other hand, some popular recreational activities in rural areas that appeal to boys but do not attract girls, such as climbing trees, swimming in a river or pond, and going to the Internet cage or cyber-cafe. Many rural girls could hardly get enough social support, self-comfort, or a sense of self-worth in their daily life. Therefore, they will be more dependent on and addicted to mobile phone use. Accordingly, we should give priority to rural females when intervention programs of MPA is implemented.

The direct effect of mobile phone addiction on suicide behaviors

In line with previous studies (Li et al., 2022; Sohn et al., 2017; Wang, Liu et al., 2014), our results of the structural equation modelling confirmed a significantly direct effect of MPA on suicide behaviors. There are several possible explanations. First, in support of the social-emotional model, adolescents with MPA generally have less social support and negative attachment with their family members and peers (Wu et al., 2016). Hence, insufficient social support and attachment would increase the risk of loneliness and interpersonal isolation, or even breed a breakdown of their intimate relationships (Herrero, Urueña, Torres, & Hidalgo, 2017), which could ultimately lead to suicidal risk (Li et al., 2022; Shinetsetseg et al., 2022). Additionally, some prior studies support that mobile phone addicts are more likely to have a failure of face-to-face communication with their social circles, which also may facilitate depressive symptoms and anxiety (Boniel-Nissim et al., 2015; Chen et al., 2016). The presence of negative affective symptoms have been identified as robust risk factors for suicide behaviors (Chen et al., 2020; Kim, 2022). Second, excessive mobile phone use may be a common coping mechanism for those adolescents with suicidality (Ismail et al., 2020). When those adolescents mean to harm themselves and/or even end their lives, mobile phones may be used to obtain information about suicide, such as finding online groups of individuals with similar thoughts of suicide, learning methods to end their lives, or even getting tools by online shopping (Lin et al., 2014). Meanwhile, the anonymity of online interactions may allow adolescents to explore suicidal information without judgment or criticism (Arrivillaga, Rey, & Extremera, 2020). Third, from an underlying neurophysiological mechanism, the visual stimulation of mobile phones could disturb functional normality in the frontal lobe of the brain, which may slow thinking, aggravate impulsiveness, and reinforce negative thoughts and behaviors (Sedgwick, Epstein, Dutta, & Ougrin, 2019; Sung-min & Byoung-jin, 2022).

Notably, regarding different involvement of suicide behaviors, mobile phone addicts are more likely to be suicide

ideators and planners from the results of multinomial logistic regression analysis. However, our analysis did not disclose a significant association between MPA and suicide attempters. This finding dose not align with some previous studies (Shinetsetseg et al., 2022). In other words, MPA may be insufficient to develop suicidal ideation and plans to suicide attempts (Kim, 2022). On the one hand, their original intention of excessive mobile phone use may be getting help from others and having access to intervention programs. Nowadays, mobile phones even have been applied as an efficient and practical intervention approach to eliminate suicidal crises based on its functions, such as online counseling and self-evaluation (Mouchabac, Leray, Adrien, Gollier-Briant, & Bonnot, 2021; Pauwels et al., 2017). On the other hand, mobile phone addicts could relieve their psychological distress, anxiety, and desperation through mobile phones by listening to music, watching videos, and even playing violent games. Subsequently, they may have less impulsiveness to attempt suicide (Huang et al., 2022). In the future study, this innovative finding should be further verified and the potential mechanism is needed to be discussed.

The mediation of poor sleep quality between mobile phone addiction and suicide behaviors

What is the exact mechanism of the relationship between MPA and suicide behaviors among adolescents? Existing literature has not answered this research question clearly and adequately. Our results indicate that MPA has indirect effect on suicide behaviors through poor sleep quality, and the mediation ratio is close to 50%. Mobile phone addicts have a tendency to spend more time at night on their mobile phones, which eventually leads to later bedtime, short total sleep duration, and circadian rhythm disturbances (Liu et al., 2017). Moreover, the screen lights from mobile phones could impact individuals' serum melatonin and cerebral blood flow (Aalto et al., 2006; Demirci et al., 2015). The aforementioned physiological changes can also facilitate tension, fatigue, vertigo, and frequent headaches, which will result in poor sleep quality (Tymofiyeva et al., 2020). Furthermore, poor sleep quality can impair individuals' frontal lobe and executive functions, weaken their problem-solving abilities, and contribute to one's mood regulation disorders and impulsive behaviors, which can ultimately increase the likelihood of suicide behaviors (Perlis et al., 2016). Moreover, poor sleep quality can also lead to dysregulations of hypothalamus/hypothalamic–pituitary–adrenal (HPA) axis, which is linked to suicide behaviors (Buckley & Schatzberg, 2005; Sarchiapone et al., 2014).

Strengths and limitations

The current study has two major strengths. First, we recruited a large-size sample of Chinese adolescents from five representative provinces across the country with a rigorous multi-stage cluster sampling method. It has an advantage of generalizing the findings of the study for adolescents around the China. Second, we controlled some confounding variables in the analysis that are highly related to MPA and suicidality, including depression, anxiety, smoking, and drinking alcohol (Gao et al., 2022; Ismail et al., 2020; Kim, 2022; Kim & Han, 2020; Li et al., 2022; Shi et al., 2021; Yang et al., 2019). Consequently, the results could be more stable and reliable.

Beyond strengths, several limitations should be acknowledged. First, this is a cross-sectional study, and the causal relationship between MPA and suicide behaviors is hard to be clarified. Therefore, a longitudinal design is essential in future research. Second, since we used a self-assessment questionnaire to measure all variables, subjective deviation is inevitable, which can increase reporting and recall bias (Huang et al., 2022). Participants might avoid answering some sensitive questions, including suicidal ideation, plans, and attempts. In future research, more reliable measurements are needed, such as interviews or objective indicators (Li et al., 2022). Third, our sample is all recruited from high schools in China and those adolescents without enrollment are ignored in the current study. Although the rate of drop out is extremely low in China, a small minority of adolescents aged 12 to 18 do not enroll in senior high schools or vocational schools after nine-year compulsory education. This population may have a higher risk of MPA and suicidality. In our next step, we will conduct a research in other groups of adolescents, such as work people and juvenile offenders.

Implications

Our findings have several practical implications for developing prevention programs for suicide among Chinese adolescents. First, considering the direct effect of MPA on suicidality, it is reasonable for parents and teachers to limit mobile phone use duration in adolescents and guide them to utilize mobile phones with beneficial functions, such as online learning and searching information (Gao et al., 2022). Concerning clinical implications, mental health professionals should monitor suicidal risk in mobile phone addicts. It is essential to recognize the early signs of suicidal ideation, plans and attempts in the high-risk population (Ismail et al., 2020). Second, our study supports that MPA could affect sleep quality, which subsequently increases the risk of suicide behaviors. Therefore, monitoring bedtime and sleep duration as well as improving sleep quality may effectively weaken the association between MPA and suicide behaviors. On the other hand, imposing restrictions on use of mobile phones at night, especially at bedtimes, may be a promising approach to prevent MPA, poor sleep quality, and suicidality (Demirci et al., 2015; Li et al., 2022). Third, we found that female adolescents from China rural areas might be the most vulnerable group to MPA, poor sleep quality, and suicide behaviors. This population deserves more attention and help when taking targeted intervention programs.

CONCLUSIONS

Mobile phone addiction has direct and indirect effects on suicide behaviors among Chinese adolescents, and poor sleep quality partially mediates the relationship between mobile phone addiction and suicide behaviors. These

findings highlight the importance of monitoring suicidality and sleep quality in adolescents who exhibit mobile phone addiction. Meanwhile, limiting mobile phone use and improving sleep quality may benefit suicide prevention among adolescents. Furthermore, the prevalence of mobile phone addiction, poor sleep quality, and suicide behaviors differs between boys and girls across urban and rural China. Therefore, it is imperative to develop targeted intervention strategies tailored by sex differences in different residences. Additionally, more efforts could give priority to helping rural females.

Founding sources: This work was supported by grants from the National Natural Science Foundation of China (grant number is 81973066 and 82173541). The funding body had no role in the design of the study and collection, analysis and interpretation of data or in writing the manuscript.

Authors' contribution: Conceptualization: Chang Peng, Yizhen Yu; formal analysis and methodology: Junhan Cheng, Chang Peng; funding acquisition: Yizhen Yu; investigation: Fajuan Rong, Yan Wang; project administration and supervision: Yizhen Yu; visualization: Yafei Tan; roles/writing – original draft: Junhan Cheng, Chang Peng; writing – review & editing: Yafei Tan, Yizhen Yu. All authors have read and approved the final manuscript.

Conflict of interest: The authors report no financial or other relationship relevant to the subject of this article.

Acknowledgements: The authors thank students who took part in the survey, parents who supported the work, teachers who assisted with the field investigation, and all investigators.

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