



# Internet use time and mental health among rural adolescents in China: A longitudinal study

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## ABSTRACT

**Background:** The digital divide between urban and rural adolescents is widening. Many existing studies have found an association between internet use and adolescent mental health, but few use longitudinal data to focus on rural adolescents. We aimed to identify the causal relationships between internet use time and mental health in Chinese rural adolescents.

**Methods:** Using a sample of 3694 participants (aged 10–19) from the 2018–2020 China Family Panel Survey (CFPS). Fixed effects model, mediating effect model and instrumental variables method was used to evaluate the causal relationships between internet use time and mental health.

**Results:** We find that more time spent on the internet has a significant negative effect on participants' mental health. This negative impact is stronger in female and senior students groups. Mediating effects analysis suggests that more time spent on the internet increase risk of mental health problems by reducing sleep duration and parent-adolescent communication. Further analysis find that online learning and online shopping is associated with higher depression scores, while online entertainment with lower depression scores.

**Limitations:** The data do not investigate the specific time spent on internet activities (e.g., learning, shopping, and entertainment), and the long-term impacts of internet use time and mental health have not been tested.

**Conclusions:** Internet use time has a significant negative impact on mental health by crowding out sleep duration and parent-adolescent communication. The results provide an empirical reference for the prevention and intervention of mental disorders in adolescents.

## 1. Introduction

Adolescent mental health problems is a public health topic of global concern (Twenge et al., 2021; Arrivillaga et al., 2020). Globally, approximately 14.2 % of adolescents (aged 10–19) experiences a mental disorder, accounting for 13 % of the global burden of disease in this age group (World Health Organization, 2021). The symptoms of depression and anxiety can first appear from childhood to adolescence and have varying degrees of severity (Philippot et al., 2022). In fact, approximately 10 % of adolescents have experienced subclinical depression (Bertha and Balázs, 2013), it is estimated that by 2030, depression alone will become the main cause of illness and disability among adolescents in the world, which lead to a huge social burden and long-term medical

costs (Blakemore, 2019). Therefore, how to prevent and intervene in adolescent mental health problems has become an important issue that needs urgent attention.

In the digital age, information technology use has become an important determinant of adolescent mental health (WHO, 2021). China, especially in rural areas, the internet penetration rate of under-age (aged 6–18) is 97.3 %, the average time of internet use on holidays is >5 h, 3.9 percentage points higher in rural areas than in towns (China Internet Network Information Center, 2022). However, with the penetration of the internet in rural areas, the negative effects of internet addiction, erosion of undesirable contents, and excessive consumption among rural adolescents have become increasingly prominent (Cyberspace Administration of China, 2018). Rural underage internet users

**Abbreviations:** WHO, World Health Organization; CNNIC, China Internet Network Information Center; CFPS, China Family Panel Studies.

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lack parental supervision and restraint when using the internet, only 38.3 % of rural underage internet users indicated that their internet use time was often restricted by parents (CNNIC, 2022). Therefore, it is important to understand the relationship between the internet use time and mental health among rural adolescents. How does internet use time affect the mental health of rural adolescents? What are the intermediate channels? Is there heterogeneity in the relationship between internet use time and mental health? The answers to the above questions can provide important empirical references for the prevention and intervention of adolescent mental health problems. It can also provide important ideas for the promotion of adolescent mental health in rural areas of other developing countries.

Currently, the academic community has not reached a consensus on the relationship between internet use and adolescent mental health. Several studies have found that internet offers many benefits to adolescents in terms of delivering information, facilitating communication and providing resources (Rosenthal et al., 2016), appropriate use of the internet by adolescents can broaden their horizons, release stress, and relieve fatigue (Slater, 2007). For example, playing online games helps user to build a bridge between the virtual and real worlds, alleviate their stress, depression or anxiety, and increased mental flexibility, which has a positive effect on their physical and mental health (Granic et al., 2014). Additionally, the internet maintains and deepens interpersonal relationships (Gross et al., 2002). Using the internet not only helps adolescents to get guidance from their relatives or friends, but also increases adolescents' social participation, self-identity and well-being (Wellman, 2001).

However, many studies have found that internet use had a significant negative impact on adolescent mental health (Kraut et al., 1998; Kwak et al., 2022; Boer et al., 2021; Liu et al., 2023). Excessive internet use time can lead to internet addiction, reduce quality of life and sleep, and produce easily negative emotions such as anxiety, depression or stress among adolescents. One study conducted a longitudinal survey of adolescents in grades 7–11 in 31 schools in the Montreal district of Canada from 2012 to 2018, and found that for every hour increase in social media use time, adolescents experienced a 0.64 increase in depression score, the mechanism of which was that media use decreased adolescents' self-esteem (Boers et al., 2019). Furthermore, a series of studies based on Korean junior and senior high school students found that internet use time was significantly correlated with adolescent's mental health problems (Kwak et al., 2022), and that excessive use of internet not only worsened sleep satisfaction and depressive symptoms (Woo et al., 2021; Frison and Eggermont et al., 2017), but also affected their adult and future generations' lives (Choi et al., 2017).

In addition, some scholars have also found no significant longitudinal association between adolescent internet use duration and early depressive symptoms (Coyne et al., 2019; Vaterlaus et al., 2020) and that internet use was neither a cause nor an outcome of depressive symptoms (Takahashi and Adachi, 2022). Whether excessive internet use among adolescents has negative effects depends on individual psychological characteristics (Helsper and Smahel, 2019) and gender differences (Twenge and Martin, 2020). For example, one study found, based on an analysis of data from an 8-year longitudinal study, that the amount of time spent online by adolescents aged 13–20 years increased with age, but there was no significant association between the amount of time spent on social media and their depression (Coyne et al., 2019).

As stated above, the following shortcomings exist in the current studies: First, the majority of prior research focused on urban adolescents (e.g., Choi et al., 2017) or a specific regional (e.g., Frison and Eggermont, 2017; Kwak et al., 2022), but there is a relative lack of research on this topic in rural areas. Due to the urban-rural digital divide, in rural areas, which are more economically and educationally backward, internet use and rural adolescents' mental health issues should be concerned. Second, most existing studies use only cross-sectional data, without sufficient tests to identify the causality and mechanism (e.g., Barry et al., 2017; Wu et al., 2022). Finally, in terms of

research methodology, existing studies have mostly conducted descriptive analysis, ANOVA or correlation analysis based on a small sample of convenience sampling (e.g., Arrivillaga et al., 2020) or survey data from a particular city (e.g., Barry et al., 2017; Coyne et al., 2019). Because of insufficient representativeness and randomness of the sample, accuracy of the results cannot be assured.

Based on this, the main contributions of this article are as follows: First, built upon displacement hypothesis analysis framework, we examined the causal relationship between internet use time and mental health among Chinese rural adolescents. Second, using CFPS 2018–2020 longitudinal data, a nationally representative survey with a large sample of data, fixed effects model and instrumental variable method were used to identify the causal relationship between Internet use and mental health. Finally, we further explored the content of internet use and mental health, and also examined the heterogeneity between the internet use time and mental health based on gender, education, and academic performance.

## 2. Theory and hypothesis

We drew upon the displacement framework to help understand the relationship between the internet use and rural adolescent mental health (Lin, 1993). The displacement hypothesis suggests that time spent on social media crowds out important activities that can improve mental health, such as good sleep, interpersonal communication with others. Adolescence is a crucial period for developing social and emotional habits, these include adopting healthy sleep patterns, exercising regularly, developing coping, problem-solving and interpersonal skills (WHO, 2021). However, excessive internet use crowds out sleep and physical activity, which may increase the risk of mental health problems for adolescents.

Next, we analyzed specifically internet use increases mental health problems among rural adolescents through which channels.

### 2.1. Sleep duration

Internet use time interferes with adolescents' sleep duration and quality (Mathew et al., 2020), and increases their depression (Tamura et al., 2017). A survey showed that >40 % of adolescents sleep <7 h at night in 2015 and that electronic device use above 2 h/day was significantly associated with sleep deprivation (Twenge et al., 2017). As most adolescents put their cell phones inside their bedrooms or under their pillows at night before going to sleep, online message alerts can disturb adolescents' sleep and lead to sleep disturbance. In addition, the peak secretion of melatonin is before going to sleep, and the light from screens such as computers and cell phones can reduce people's secretion of melatonin (Cain and Gradisar, 2010). One study found that screen time was significantly associated with adolescent depression and that there was a significant mediating effect of less sleep between screen time use and adolescent depression (Wang et al., 2021).

### 2.2. Physical exercise

Growing evidence shows that excessive electronic screen time is significantly associated with lack of outdoor activity among adolescents (Almaqawi and Albarqi, 2022). Internet addicted children are more likely to have sedentary habits and lack of physical exercise and leisure activities (Zhou et al., 2022). There is a significant relationship between time spent on the internet and adolescents' exercise habits: the more time spent on the internet, the less time on the outdoor and physical activities, especially those adolescents who own computers (Wang et al., 2012). Clinical studies have also shown that physical activity was an important factor in reducing anxiety and depressive symptoms in individuals (McDowell et al., 2019; Oberste et al., 2020). Physical activity was protective of adolescent mental health regardless of the amount of exercise (Zhou et al., 2022), and appropriate physical activity is

associated with lower depressive symptoms among adolescents (Bailey et al., 2018).

### 2.3. Parent-adolescent communication

Some scholars have found that the internet had a negative impact on interpersonal relationships (Kraut et al., 1998; Wang et al., 2012). In the virtual world of the internet, individuals do not appear as their real identities, which provides a channel for adolescents to express themselves but also reduces their communication with their parents, and causes adolescents' mental health problems. A negative association between higher internet attachment and high-quality parent-adolescent communication has been proven (Zhu et al., 2015), and adolescents' dependence on the internet may also lead to a decrease in their social interactions, which is likely to change their psychological states and behaviors and affect negatively the quality of parent-adolescent communication (Restrepo et al., 2020), while some studies have found that adolescents who have better interpersonal relationships with their parents are more emotionally stable, more socially competitive, and have fewer psychological problems (Schneider et al., 2001). Spending more time on virtual online platforms can reduce the quality of parent-adolescent communication, causing adolescents to be frustrated, anxious, and uncomfortable (Cuong et al., 2021).

Based on the above theoretical analysis, we propose the following research hypotheses to be tested in the subsequent empirical analysis:

**Hypothesis 1.** Internet use time might have a significant negative impact on the mental health of Chinese rural adolescents.

**Hypothesis 2.** Sleep duration may mediate the relationship between internet use and mental health.

**Hypothesis 3.** Physical exercise may mediate the relationship between internet use and mental health.

**Hypothesis 4.** Parent-adolescent communication may also mediate the relationship between internet use and mental health.

## 3. Methods

### 3.1. Survey sample

The data in this paper comes from the latest internationally representative 2018–2020 China Family Panel Studies (CFPS), a nationwide, large-scale, multidisciplinary social survey organized by the China Social Science Research Center of Peking University. The CFPS sample covers the population of 25 provinces in China. These 25 provinces account for approximately 95 % of the total population of the country, and thus the CFPS sample can be considered as a nationally representative sample. Considering the huge regional differences in China, and in order to save survey costs and improve the representativeness of sampling, this survey used systematic probability sampling with multi-stage, implicit stratification and probability proportional to size. The project used computer-assisted survey technology to conduct interviews. CPFS focuses on changes in socioeconomic, educational returns, family and population health in China. The collection contains survey data at the individual (adult and child), household, and community levels. We used the 2018 (wave 4) and 2020 (wave 5) longitudinal panel data, this survey includes cell phone networks, educational history, cognitive behavior, and mental health of adolescents. Based on the needs of the study, we selected participants aged 10–19 years living in rural areas of China as the sample for analysis. There were 1998 participants surveyed in wave 4, 1696 participants surveyed in wave 5. 2068 participants surveyed at both time points. The total sample of female participants was 1745, representing a total sample ratio of 47.24 %.

### 3.2. Measures

#### 3.2.1. Mental health

We used depression as a proxy variable for mental health, and adolescents' depression was assessed at the 20-item, self-reported Center for Epidemiological Studies Depression Scale for Children (CES-D20). The scale contains a total of 20 items, participants rated each item by its frequency over the past week. Depression items include “*I feel depressed*”, “*I felt lonely*” and “*I feel like life can't go on*”, etc. with a response four-point scale (1 = not at all, 2 = several days, 3 = more than half of the days, 4 = Nearly every day). Therefore, the depression scores of the 20 items range from 20 to 80. Higher scores indicate higher levels of depression in participants. Additionally, this survey also gives an 8-item depression scale (CES-D8). We also used an 8-items depression scale to test the reliability of baseline study findings.

#### 3.2.2. Internet use time

Participants responded to one item regarding how many hours they spend in a typical day using mobile internet (e.g., Smartphone, Ipad). This survey questionnaire asked “*In general, how much time do you spend online on your mobile device each day?*” The variable takes values in the range 0–24 h, which is used in this paper to measure internet use time. In addition, CFPS also investigated the content of internet use, including four specific categories of internet activities: online learning, online shopping, online socializing and online entertainment. Participants respond yes = 1, no = 0. Sample items included, “*Have you used online learning every day in the past week (e.g., Watching or Listening to various courses on platforms)*”, “*Have you been shopping online in the past week*”, “*Whether to use the internet for social activities (e.g., chatting on WeChat, tweeting, etc.)*”, and “*Did you use the internet for entertainment (e.g., watching videos, downloading songs, etc.) in the past week*”.

#### 3.2.3. Control variables

Referring to related research (Choi et al., 2017), the control variables in this paper included both participants basic characteristics and family characteristics. Individual characteristics included gender (male = 1, female = 0), age, education level (years), self-assessed health (5 points Likert scale, 1 = very healthy, 5 = very unhealthy), academic performance (5 points Likert scale, 1 = very dissatisfied, 5 = very satisfied), academic stress (5 points Likert scale, 1 = no pressure, 5 = a lot of pressure), smoke (whether smoke, yes = 1, no = 0), class leader (yes = 1, no = 0), board (whether boarding school, yes = 1, no = 0). Family characteristics include education expenditure (last year's total expenditure on family education, yuan), parental relationship (number of parental arguments in the past month).

#### 3.2.4. Mediating variables

Based on the previous displacement hypothesis, the mediating variables in this paper were selected as sleep duration, physical exercise, and parent-adolescent communication to examine the possible mediating effects between internet use time and mental health. Specifically, the sleep duration (good = 1, insufficient = 0), sample surveyed “*What time do you usually go to bed at night?*” We assign a value of 1 to participants who fall asleep at 10 pm and before, indicating good sleep. Otherwise, we assign a value of 0, indicating insufficient sleep. Meanwhile, 18 and 19 years old who fall asleep after 11 pm should be coded as insufficient sleep given that the recommendation by the government is 11 pm.<sup>1</sup> Physical exercise was measured by using the question “*In the past year,*

<sup>1</sup> In order to ensure that primary and secondary school students have sufficient sleep time and promote their healthy physical and mental, the Ministry of Education of the People's Republic of China has issued a document stipulating that the bedtime for adolescents at night is generally no later than 22:00 for middle school students and 23:00 for high school students (Ministry of Education of the People's Republic of China, 2021).

how many minutes you physically exercise every day”, continuous variable (minutes/day). Parent-adolescent communication was measured by “In the past year, when talking with your parents, they have been able to share their feelings and opinions with you calmly”, ordinal variable, 1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = always. The higher the score is, the better the parents and adolescents communicate.

### 3.3. Model

To identify the causal relationship between internet use time and mental health, we established a fixed effects regression model, with the following form of model setting.

$$y_{it} = \alpha 0 + \beta \text{internet}_{it} + \gamma X_{it} + \lambda t + \theta p + \varepsilon_{it} \quad (1)$$

where  $i$  indexes participant,  $t$  indicates year (2018, 2020),  $y_{it}$  denotes the self-reported depression score of participant  $i$  in year  $t$ . The  $\text{internet}_{it}$  denotes the internet use time of participant  $i$  in year  $t$ .  $\beta$  denotes the estimated coefficient of internet use time.  $X_{it}$  is a set of individual-level and family-level control variables.  $\gamma$  is the estimated coefficient of each control variable in the group.  $\alpha p$  denotes province fixed effects, to control the effects of unobserved factors that do not vary over time at the province level on individual internet use time.  $\lambda_t$  denotes time-fixed effects to control those influences that do not vary with the individual at the time level.  $\varepsilon_{it}$  is a residual term.

### 3.4. Statistical analysis

The data were analyzed by Stata15 (Stata Corp LLC). Frequency and percentage applied to sample descriptive statistics, R-squared was used to account the fit of the regression equation, and fixed effects regression analysis were conducted to assess the association between internet use time and mental health in participants. We tested the presence of weak instrumental variable problems by using the F-statistic and the standard errors (SE) to measure the dispersion of the sample statistics in all models.

## 4. Results

### 4.1. Basic characteristics of participants' internet use

Table 1 shows the basic characteristics of the overall sample, as well as a basic description of the participants' internet use time and use content based on age group. First, the total sample of participants in this survey was 3694. The mean depression score of participants in the overall sample was 30.64, but there was a slight upward trend in the depression score of participants as their age increased. The majority of participants used the internet for <1 h ( $n = 2061$ , 55.79 %), and the number of participants who used the internet for >10 h/day was relatively small, accounting for only 1.41 %. The sample with >5 h of internet use was concentrated among the age group of 16 years and older. In addition, the overall sample had the highest percentage of participants online entertainment ( $n = 885$ , 62.21 %) and the lowest percentage of participants online shopping (28.91 %). Among the age subgroups, online learning had the highest percentage of participants aged 16 and older (59.67 %), online socializing and entertainment was more prevalent in each age group, and these two types of internet use accounted for >80 % in the 16 and older subgroup, and online shopping was more prevalent among participants aged 16 and older (55.97 %) than among participants aged 10–12 (5.9 %). This indicates that senior students are more likely to engage in online shopping and socializing. The proportion of all four types of internet use content increases with age.

### 4.2. Baseline regression results

The baseline results are reported in Table 2. We firstly conducted regression analyses using CES-D20 as the explanatory variable with internet use time to provide baseline estimates. In column (1) we only controlled province fixed effects and time fixed effects, and found a positive effect of more time spent on the internet on participants' mental health problems ( $\beta = 0.158$ ,  $p < 0.05$ ). In column (2) we further included control variables, which showed that a positive effect of internet use time on participants' mental health problems ( $\beta = 0.173$ ,  $p < 0.05$ ), and the predictors in the model collectively explained 29.6 % of the variance in adolescents' mental health ( $R^2 = 0.296$ ). In addition, columns (3) and (4) were regressed using CES-D8 as the explanatory variable, and we found that the above findings still held true. With the addition of fixed effects and control variables in column (4), internet use time still had a significant negative effect on mental health ( $\beta = 0.086$ ,  $p < 0.05$ ). The above findings supported Hypothesis 1.

### 4.3. Robustness test

Use and gratification theory shows that depression may predict increased future use of social media, there may be reverse causality between mental health and internet use time. We applied the instrumental variables approach to identify causal relationship. Drawing on existing ideas of instrumental variable construction (Sabatini and Saracino, 2017), we used community network intensity as an instrumental variable.<sup>2</sup> The internal logic of this instrumental variable is that, the level of community network intensity reflects the overall network infrastructure construction status of that community and the network access of other adolescents in the community, and adolescents' internet use time is influenced by the network informatization in the community and the peer effect of community (Ning et al., 2021). The correlation of the instrumental variables was satisfied. Meanwhile, the level of network informatization in the community reflected the overall network intensity of the community and was almost independent of individual psychological states, satisfying the exclusion restriction of the instrumental variable.

Table 3 shows the estimated results by using two-stage least squares (2SLS) regressions, with columns (1) and (2) which use CES-DC20 as the explanatory variable. The results show that in the first stage the average ratio of community internet use has a significant positive correlation with internet use time. The F-statistic of 168.06 is >10, indicating that there is no weak instrumental variable problem (Stock and Yogo, 2005). Meanwhile, column (2) shows that the effect of internet use time on rural adolescents' mental health remains significantly positive. The regression coefficient of 0.254 is higher than the baseline regression coefficient ( $\beta = 0.173$ , column 2 of Table 2), this verifies the reliability of the baseline regression's results. Meanwhile, after using instrumental variables regression CES-DC8 as the explanatory variable, the results in columns (3) and (4) indicate that internet use time continues to have a significant positive effect on mental health problems, our research findings remain robust.

### 4.4. Mediation analysis

We referred to the mediating effects analysis method proposed by Baron and Kenny (1986).

<sup>2</sup> Obtained by calculating the average internet usage time of other participants in the community, because 2020 CFPS does not give community codes, the new individual sample of 2020 was not included in the analysis sample when calculating the community-level instrumental variables, and a total of 2068 samples were ultimately used for regression analysis of the instrumental variables.



**Table 1**  
Characteristics of participants' internet use.

	Total sample (n = 3694)		10–12 years old (n = 1338)		13–15 years old (n = 1275)		≥16 years old (n = 1081)	
	Sample	%	n	%	n	%	n	%
Internet use time								
<1 h	2061	55.79	991	74.07	661	51.84	409	37.84
1–2 h	685	18.54	212	15.84	271	21.25	202	18.69
2–5 h	643	17.41	104	7.77	242	18.98	297	27.47
5–10 h	253	6.85	26	1.94	86	6.75	141	13.04
>10 h	52	1.41	5	0.37	15	1.18	32	2.96
Content of internet use								
Online learning								
No	2053	55.58	958	71.60	659	51.69	436	40.33
Yes	1641	44.42	380	28.40	616	48.31	645	59.67
Online shopping								
No	2626	71.09	1259	94.10	891	69.88	476	44.03
Yes	1068	28.91	79	5.90	384	30.12	605	55.97
Online socializing								
No	1511	40.90	919	68.68	438	34.35	154	14.25
Yes	2183	59.10	419	31.32	837	65.65	927	85.75
Online entertainment								
No	1396	37.79	790	59.04	410	32.16	196	18.13
Yes	2298	62.21	548	40.96	865	67.84	885	81.87

**Table 2**  
The associations between internet use time and mental health.

	CES-D20		CES-D8	
	(1)	(2)	(3)	(4)
Internet use time	0.158** (0.072)	0.173** (0.072)	0.078** (0.037)	0.086** (0.036)
Control variables	No	Yes	No	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	3694	3694	3694	3694
Adj. R-sq	0.272	0.296	0.274	0.298

Note: Control variables include gender, age, education level, self-assessed health, academic performance, academic stress, smoke, class leader, board, education expenditure, parental relationship. Robust standard errors in parentheses.

\*\* Indicates statistical significance at 5 %.

**Table 3**  
Internet use time and rural adolescent mental health: instrumented results.

	First stage	Second stage	First stage	Second stage
	(1)	(2)	(1)	(2)
Community network intensity	0.983*** (0.051)		0.983*** (0.076)	
Internet use time		0.254* (0.138)		0.126* (0.070)
First stage F-statistic	168.06***		168.10***	
Control variables	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	2068	2068	2068	2068
R <sup>2</sup>	0.391	0.107	0.391	0.106

Note: Control variables consistent with those in the basic regression. Robust standard errors in parentheses.

\*\*\* Indicates statistical significance at 1 %.

\* Indicates statistical significance at 10 %.

Step 1: Show that the internet use time is correlated with the outcome (estimate and test path c in the below figure), this step establishes that there is an effect that may be mediated.

Step 2: Show that the causal variable is correlated with the mediator (estimate and test path a). This step essentially involves treating the mediator as if it were an outcome variable.

Step 3: Regressing internet use time and mediating variables together with mental health (estimate and test path b), the product of coefficients of  $a$  and  $b$  denoted the indirect effect ( $a \times b$ ), indirect effect  $a \times b$  is the measure of the amount of mediation,  $c'$  denotes the direct effect of internet use time on mental health after the inclusion of mediating variables.

The total effect is the sum of the direct and indirect effects ( $c = c' + ab$ ). In this paper, we use the Sobel test, first proposed by Sobel (1982), to test whether the mediating effect holds.

Table 4 shows the results of the mediating effect analysis. First, in the analysis using sleep duration as a mediating variable, the Sobel test passed the test of mediating effect, and the coefficient of indirect effect ( $a \times b$ ) was significant ( $\beta = 0.022$ ,  $P < 0.001$ ), and the direct effect  $c'$  was also significant ( $\beta = 0.076$ ,  $P < 0.05$ ), indicating that sleep duration played a partial mediating role between internet use time and mental health. The mediating effect was 22.48 % of the total effect ratio. Second, we tested the results of the mediating effect of physical exercise, and the results show that the estimated coefficient of the indirect effect is not significant and does not pass the Sobel test, and the mediating effect does not hold. Finally, the analysis using parent-adolescent communication as a mediating variable passed the Sobel test, the indirect effect is significant ( $\beta = 0.031$ ,  $P < 0.05$ ) and the direct effect is also significant, indicating that there is a partial mediating effect of the model, with a mediating effect of 24.02 %. Hypothesis 2 and Hypothesis 4 of this study were tested, but this result did not support Hypothesis 3.

#### 4.5. Heterogeneity analysis

The internet provides a diverse and rich world in which different purposes, contents, and internet use time are accompanied by different contexts, mechanisms, and behaviors resulting in different consequences (Boers et al., 2019). Therefore, model 1 in Table 5 further examines the relationship between the content of internet use and mental health. The results of model 1 of Table 5 suggest that online learning and online shopping are associated with higher depression ( $\beta = 0.888$ ,  $P < 0.01$ ). However, the relationship between online entertainment and depression scores are significantly negative ( $\beta = -1.239$ ,  $P < 0.01$ ). We further examined the heterogeneity between the internet use and mental health, generating interaction terms for internet use time with gender, education level, academic achievement. The results in model 2 of Table 5 shows that the effect of greater internet use on mental health was significantly negative for female adolescents compared to male adolescents. The coefficient of the interaction term for internet use time and

**Table 4**  
Mediation effect test.

	Sleep quality			Physical exercise			Parent-adolescent communication		
	$\beta$	SE	P-value	$\beta$	SE	P-value	$\beta$	SE	P-value
Sobel-mediation test	0.022	0.006	0.000	−0.001	0.001	0.438	0.031	0.011	0.007
a coefficient	−0.019	0.002	7.0e−12	0.688	0.395	0.081	−0.022	0.007	0.004
b coefficient	−1.135	0.261	0.000	−0.002	0.002	0.387	−1.401	0.182	1.4e−14
Indirect effect, $a \times b$	0.022	0.006	0.000	−0.001	0.001	0.438	0.031	0.011	0.007
Direct effect, $c'$	0.076	0.045	0.091	0.097	0.045	0.029	0.099	0.056	0.080
Total effect, c	0.098	0.044	0.028	0.096	0.044	0.031	0.130	0.057	0.023
Proportion of total effect that is mediated, $ab/c$	22.48 %			1.16 %			24.02 %		

Notes: All models were estimated using fixed effects model regression.  $\beta$  denotes regression coefficient, SE indicates standard error. Control variables consistent with the baseline regression are also included in the model.

**Table 5**  
Heterogeneous analysis of the relationship between internet use and mental health.

	Model 1	Model 2	Model 3	Model 4
Online learning (reference: no)	0.462* (0.263)			
Online shopping (reference: no)	0.888*** (0.269)			
Online socializing (reference: no)	1.123 (0.848)			
Online entertainment (reference: no)	−1.239*** (0.321)			
Internet use time		0.172*** (0.066)	−0.266* (0.156)	0.168 (0.133)
Gender $\times$ internet use time		−0.139* (0.079)		
Education level $\times$ internet use time			0.039** (0.016)	
Academic performance $\times$ internet use time				−0.025 (0.040)
Control variables	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes
Observations	3694	3694	3694	3694
R <sup>2</sup>	0.108	0.126	0.127	0.126

Note: standard errors are given in parentheses. Control variables consistent with those in the basic regression.

\*\*\* Indicates statistical significance at 1 %.

\*\* Indicates statistical significance at 5 %.

\* Indicates statistical significance at 10 %.

education level in model 3 is significantly positive, indicating that the longer the years of education, the more significant the negative impact of internet use time on mental health ( $\beta = 0.039$ ,  $P < 0.05$ ). The interaction terms for internet use time and academic performance in model 4 is not significant, indicating that the internet use does not have a significant negative impact on mental health among participants with better academic performance compared to those with poorer academic performance.

## 5. Discussion

This study aimed to examine the causal relationship between the internet use time and the mental health of rural Chinese adolescents, and analyzed this relationship' mediating effects and heterogeneity. To the best of our knowledge, few studies have focused on internet use and mental health of Chinese rural adolescents, and relatively scant research has focused on the content of internet usage. At the same time, we used data from the most recent and very representative large sample survey in China, and the results are more representative than the small or convenience sample surveys used in existing related studies. We found a significantly negative effect of internet use on mental health, with sleep duration and parent-adolescent communication mediating this negative

relationship. However, there was significant heterogeneity in the effects of different internet use content on mental health.

### 5.1. Internet use time negatively impacts the mental health of Chinese rural adolescents

This study supports the [Hypothesis 1](#). We found a significant negative impact of internet use time on adolescent mental health, which is consistent with previous research findings ([Barry et al., 2017](#); [Alavi et al., 2011](#); [Tokunaga and Rains, 2010](#); [Wu et al., 2022](#)). Many studies have shown that spending too much time on the internet can cause many mental health problems in adolescents, such as hyperactivity disorder, depression, and anxiety disorder ([Choi et al., 2017](#)). Adolescents who spend more time online are more likely to experience interpersonal problems, because they spend less time in communicating with others, and this can lead to mental health problems such as anxiety and depression ([Woods and Scott, 2016](#)), also >5 h of internet use in a day can be a strong predictor of problematic internet use behavior, which is significantly associated with loneliness, psychological stress, and mental illnesses like depression ([Wu et al., 2022](#)).

### 5.2. Sleep duration and parent-adolescent communication play a significant mediating role

Our study also confirms [Hypothesis 2](#) and [Hypothesis 4](#). Sleep duration and parent-adolescent communication play a significant mediating role between the internet use time and mental health. First, it has been shown that 86 % of adolescents leave their cell phones in their bedrooms at bedtime, that sleep is often disturbed by SMS or social media alerts and that they experience anxiety from missing content of text message ([Skierkowski and Wood, 2012](#); [Woods and Scott, 2016](#)). In addition, the peak secretion of melatonin is before going to sleep, and the light from screens such as cell phones and computers can reduce secretion of melatonin and thus lead to insomnia, while browsing internet information before going to sleep tends also to increase the excitement of the brain and make it difficult to fall asleep ([Cain and Gradisar, 2010](#)), increasing the risk of depression and anxiety ([Alfano et al., 2009](#)). Second, this article found that internet use time reduced significantly communication and contact between rural adolescents and their parents, thus affected negatively adolescents' physical and mental health. The displacement hypothesis suggests that spending more time on virtual online platforms can reduce the quality of parent-adolescent communication, causing adolescents to be frustrated, anxious, and uncomfortable ([Cuong et al., 2021](#); [Coyne et al., 2019](#)).

### 5.3. Online learning and online shopping were significantly associated with higher risk of mental health problems

We also explored the relationship between the content of internet use and mental health. First, we found online learning increased significantly depression among rural adolescents. According to the data of China Internet Network Information Center, the proportion of teenage

internet users who frequently used the internet for learning in the past six months reached 88.9 % (CNNIC, 2022). During the epidemic prevention and control period online courses become the norm, young people who study online, listen to lectures and complete assignments, are isolated from their familiar social circles and society for a period of time, which can easily lead to psychological discomfort and even cause symptoms of loneliness (Fawaz and Samaha, 2021). Adolescents participating in virtual learning also reported feeling less social connection and higher rates of mental health problems, in comparison to their peers who could attend school in-person or in a hybrid model (Pelucio et al., 2022). Second, it is worth noting that online entertainment reduced significantly adolescent's depression, which is not consistent with the findings of existing studies (Pea et al., 2012). In 2021, the proportion of underage internet users who regularly watch short videos and download songs will be 47.6 % and 63 %, respectively (CNNIC, 2022). Possible explanations are that online entertainment relieve adolescents' academic stress and become an entertainment platform for adolescents to relax and unwind. Especially for adolescent users in rural underdeveloped areas, the emergence of short videos has filled the gap of information and knowledge that are difficult for them to access and enhanced adolescent's well-being to some degree.

#### 5.4. The negative effects of internet use time on mental health were stronger in female and senior students groups

Last but not least, we also examined the heterogeneity of internet use time affecting adolescents' mental health based on gender, education level and academic performance. We found that increased internet use was significantly associated with lower depression scores in male adolescents compared to female adolescents. Female adolescents are more likely to increase risk of mental health problems when using the internet, as confirmed in existing studies (Faravelli et al., 2013). Female adolescents tend to use social networking sites more (Barker, 2009), experience poorer sleep quality (Lazaratou et al., 2005), have lower self-esteem (Bachman et al., 2011) and reach higher levels of anxiety and depression (Woods and Scott, 2016). We also found that more internet use time was significantly and positively associated with mental health problems among adolescents who were senior students, which is in line with some prior studies (Kozina, 2014). The increase of internet use from 10 years old to 19 years old might be due to the necessity to follow more courses online (closed schools) and the legal rights to do online shopping from age 16 and older. Some data show that the proportion of high school students who frequently shop online and use social networking sites both exceed the average of underage internet users by >23 percentage points, and at the same time, the school curriculum is longer for 16–19 years old than 10 years olds. Some studies show that the proportion of high school students who study online is as high as 91.7 % (CNNIC, 2022), which makes them sleep less and more inclined to have depression and anxiety problems (Garmy et al., 2012).

#### 5.5. Limitations and future studies

We note the following limitations in our study, and we have also provided some directions for research in the future. First, the data used in the article did not investigate the time spent on internet activities. We don't know when the internet use was (was it during bedtime as they speculate) and how much the adolescents spent per day on each of the 4 activities, the timing of use of specific internet activities may have different effects on adolescents' sleep or mental health, and the long-term impacts of internet use time and mental health have not been tested. Future research can further enrich the content information of internet use based on a large sample survey, which can provide a more scientific policy basis for promoting the physical and mental health of young people. Second, this paper used the CES-D to measure adolescent mental health. The CES-D is a self-reported score and not a clinical diagnostic measure, and participants reported results may not be

precise. Depression is a complex psychological and biological problem, and consideration of biomarker associated with depression in future studies could better identify potential mechanisms by which the internet affects mental health. Lastly, the empirical region of this article is rural China, and internet use preferences and socioeconomic contexts vary across countries and regions, so the conclusions drawn in this paper cannot be generalized to other countries yet, and policy makers should be cautious when formulating public policies to address internet use and mental health issues, and future related studies should focus on comparisons between different countries or regions.

## 6. Conclusion

In conclusion, the main findings of this paper are as follows: First, internet use time had a significant negative effect on the mental health of rural Chinese adolescents. Second, mediation effect analysis showed that internet use time crowded out sleep time and parent-adolescents communication, increasing risks of mental health problems. Third, heterogeneity analysis showed that the negative effects of internet use on mental health were stronger among females, senior students groups. Further analysis found that online learning and online shopping is associated with higher depression scores, while online entertainment with lower depression scores.

The above findings suggest that the government should introduce active policy measures to intervene in rural adolescents' online time and promote their healthy physical and mental development. First, the government should introduce further internet intervention policies and regulations, make a scientific sleep policy program to guide adolescents to cultivate a reasonable rest schedule and lifestyle habits. Second, schools and society should pay more attention to rural adolescents' mental health, especially girls, more educated adolescents during their mental health counseling, strengthen supervision and management of their use of cell phones. Furthermore, parents should communicate more frequently with their children, focus on their children's psychological state, guide their children to use the internet correctly and cultivate a positive mindset. For some children in rural areas whose parents work somewhere else and whose guardians find it really difficult to supervise minors on the internet, support can be provided by the community or social organizations to help them reduce their internet use time.

## CRedit authorship contribution statement

MJQ and SL conceptualized this research. MJQ were responsible for the methodology. MJQ conducted software analyses. SL conducted the necessary validations. MJQ conducted a formal analysis and managed the investigation. MJQ, and SL gathered resources, curated all the data, wrote/prepared the original draft, and were responsible for project administration. MJQ and SL reviewed and edited the manuscript; were responsible for visualization; supervised the project; and acquired funding. All authors contributed to the article and approved the submitted version.

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## Ethics approval statement

CFPS data collection was reviewed and approved by the Biomedical

Ethics Committee of Peking University (IRB00001052-14010), all participants have signed the informed consent.

### Patient consent statement

All participants expressed informed consent to participate in the study.

### Declaration of competing interest

The authors declare no conflict of interest.

### Data availability

The data used in this paper come from the public survey data released by the China Social Science Survey Center (ISSS) of Peking University, and the data is available at <http://www.issc.pku.edu.cn/cfps/>.

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